

ESTIMATING MANAGED LANES DOOR-TO-DOOR TRAVEL TIMESAVINGS USING SHORTEST PATH ALGORITHMS

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degrees
Master of Science in the
School of Civil and Environmental Engineering and
Master of City and Regional Planning in the
School of City and Regional Planning

Georgia Institute of Technology
December 2019

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Date Approved: August 23, 2019

ACKNOWLEDGEMENTS

First and foremost I would like to thank my advisors, Dr. Randall Guensler, Dr. Tim Welch, and Dr. Haobing Liu for their support and guidance on this thesis. Their dedicated teachings over the past two years have equipped me with the knowledge and skillsets to finish this research. I would also like to thank the State Road and Tollway Authority (SRTA) for letting me participate in their “Vehicle Occupancy, Vehicle and Person Throughput, and Carpooling Demographics of SRTA’s Managed Lane” project, which serves as the main inspiration for this thesis.

I am also grateful to all my lab mates, especially to Hanyan “Ann” Li and Yuanbo “Cody” Wang for their development and coding support on the shortest path algorithm, and to Yingping Zhao for her help in generating trip inputs from the Atlanta Activity Based Model. I am also thankful to all my colleagues whom I have worked with for the past year on the SRTA project. Their hard work both on field and in lab helped establish a license plate database for the study area, which serves as a crucial input to this research.

Thank you to my parents and my brother whose hard work and support gave me the opportunity to study in the U.S. to accomplish my academic goals. I would also like to thank all my family members for their long-term support throughout the past two years of my study. Even though we are 8,000 miles apart, your encouraging words keep me motivated every single day.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABM Activity Based Model

ARC Atlanta Regional Commission

DTA Dynamic Traffic Assignment

GDOT Georgia Department of Transportation

GTFS General Transit Feed Specification

GP General Purpose (lane)

HOT High Occupancy Toll (lane)

HOV High Occupancy Vehicle (lane)

O-D Origin-Destination (from an origin to a destination)

ML Managed Lane

NWC Northwest Corridor (managed lane facility)

SRTA State Road and Tollway Authority

TAZ Traffic Analysis Zone

SUMMARY

Implementing managed lanes, such as high-occupancy toll lanes, within existing urban highway corridors has become increasingly common in cities that want to provide a reliable transportation option but lack sufficient right-of-way to construct new corridors. This study develops a framework that utilizes a shortest path algorithm to compare before and after commute routes and estimate the change in door-to-door travel time offered by managed lane facilities. Using this modeling approach, a case study is explored for the Northwest Corridor (NWC) managed lane facility located in the Atlanta, Georgia, region. The shortest path routines predict that the facility provides a 21.0% - 27.1% decrease in door-to-door travel time for the NWC managed lane users, and a 5.8% – 12.0% travel time decrease for non-NWC general-purpose lane users, for corridor travelers departing home between 6:30 and 8:30 A.M. (traversing the corridor between 6:30 A.M. and 10:00 A.M.). This framework can be easily customized and applied to any other commute route/time change assessment for major managed lane projects.

CHAPTER 1. INTRODUCTION

Faced with the emerging congestion on urban Interstate highways, transportation agencies have been promoting strategies to better manage the current highway infrastructure and increase the capacity of traffic lanes. The term “managed lane” can be broadly defined as lanes operated with a variety of management techniques to improve freeway efficiency and meet corridor objectives (Collier & Goodin, 2004). Within this broad category, the types of managed lanes include high-occupancy vehicle (HOV), high-occupancy toll (HOT) lanes, and other special-use lanes, such as truck-only and bus-only lanes.

Many studies have been conducted to evaluate the effectiveness and efficiency of managed lanes, as well as the value of time (VOT) and willingness-to-pay for managed lanes (Brownstonea, et al., 2002) (Burris, et al., 2012). Most agencies evaluate success of managed lanes based upon survey results and timesavings along a corridor, based upon speed data (Bill R. & Burris, 2004). However, few studies have assessed the door-to-door travel time- savings provided by these lanes, which may be more influential in willingness to pay functions than the time saved on the corridor alone. This study aims to develop a framework that can be used to evaluate not just the time saved while operating on the manage lane segments, but the aggregated door-to-door time saved (and percentage time saved) for each commuting trips impacted by the managed lane facility. To quantify these potential savings, this study employs travel demand model outputs, to obtain detailed route information for all trips that use the managed lanes corridor, and shortest path algorithms applied to a coded roadway simulation network. With detailed route change information in place, timesavings for both managed lane and non-managed lane users can be estimated and compared.

This paper focuses on the new managed lane facility on the Northwest Corridor (NWC) in Northwest Atlanta as the case study. The newly constructed reversible managed lane facility opened in September 2018. The NWC managed lane facilities include a 10-mile two-lane section on I-75, a 5.7-mile single-lane section on I-75, and a 10.7-mile single-lane section on I-575. The project was designed to help alleviate heavy commuting traffic from the northeastern suburbs into downtown Atlanta, but mostly to provide express buses and commuters willing to pay a toll a more reliable travel times into and out of Atlanta. The effectiveness of the corridor is interest to the State Road and Tollway Authority (SRTA), the agency that manages the facility, and the Georgia Department of Transportation (GDOT). A schematic map of the NWC managed lanes provided by SRTA is shown below in Figure 1.

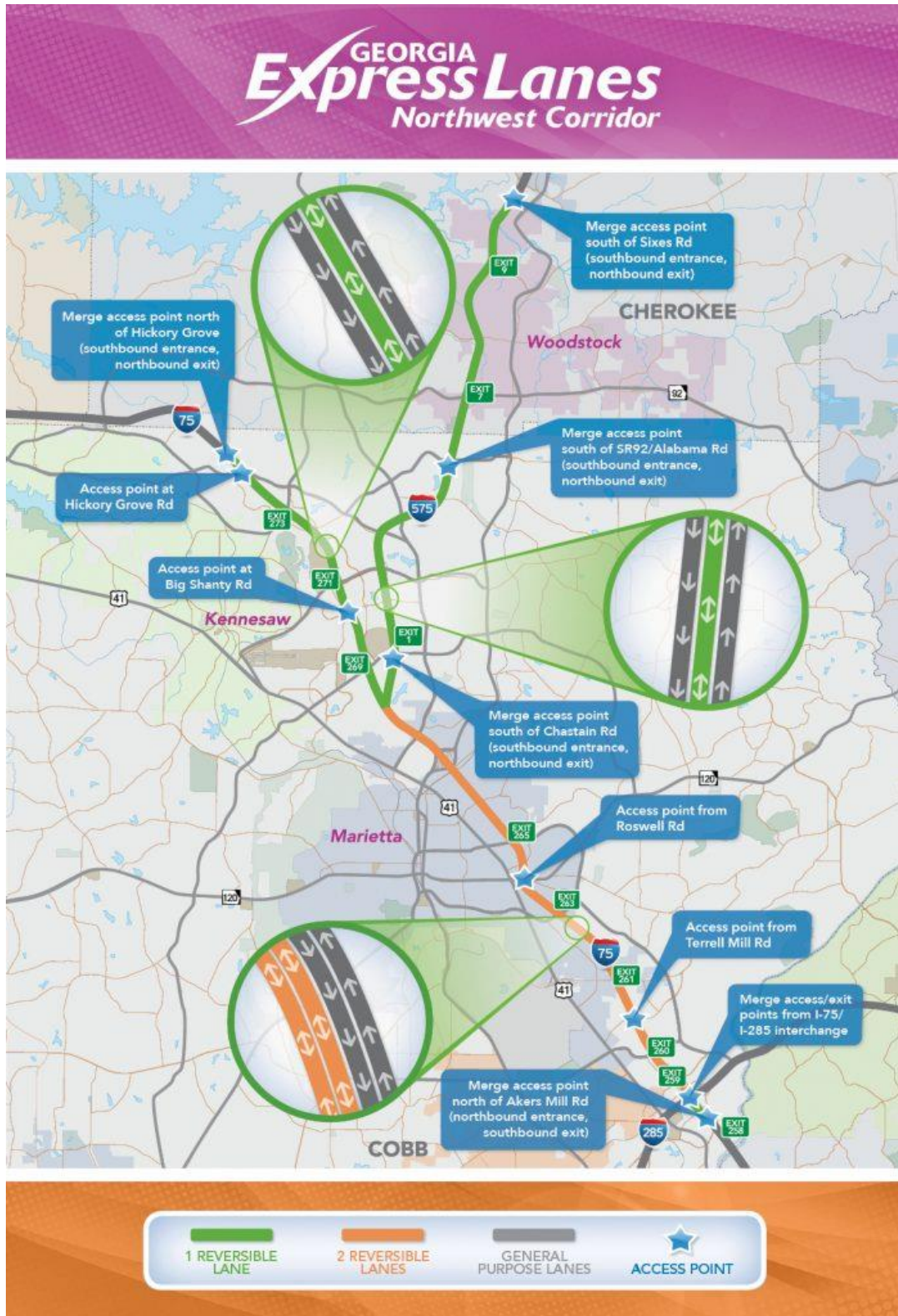


Figure 1. Map of the NWC, Managed Lanes, and the Access Points (SRTA, 2018)

Chapter 3 of this thesis describes the methodology employed in the trip generation and shortest path modeling process and Chapter 4 identifies the data sources and pre-processing routines used for the NWC managed lane case study. Chapter 5 presents travel timesavings resulting from the sampled origin-destination pairs for those who are paying to use the managed lanes. Chapter 6 presents quantified travel timesavings on a localized level at four access points on I-75. Chapter 7 then provides conclusions, followed Chapter 8 with limitations and future work.

CHAPTER 2. LITERATURE REVIEW

The concept of managed lanes, specifically HOV lanes, started in 1969 in New Jersey and Virginia in the form of bus-only lanes (Fuhs & Obenberger, 2002). Since then, managed lanes have been implemented with the purpose of encouraging carpools through a significant, reliable travel time incentive (Burris, Ungemah, Mahlawat, & Pannu, 2009). However, while some HOV facilities proved to be effective, others were found to be underutilized because carpooling trips account for only a small portion of total vehicle trips, and the fact that not all carpooling trips use the HOV lane (Li, 2001). Also, it has been shown that HOV lanes do not necessarily incentivize carpooling that reduce the vehicle trips, because as many as 43% of carpools are related family members, a.k.a. “fampools” (Fielding & Klein, 1993). As a result, a large portion of HOV systems around the US has been underutilized. In California, 81% of the state’s HOV facilities evaluated failed to meet their target flow during the PM peak hours (Varaiya, 2007).

Alternatively, HOT lanes manage highway traffic more efficiently than HOV lanes, while also taking into consideration infrastructure and operations funding. HOT lanes are similar to HOV lanes but they allow single-occupant vehicles to utilize the facility for a price paid through a toll (Duarte, 2013). HOT lanes have been gaining popularity in metro areas over the last two decades. The first HOT in the US was implemented in State Route 91 (SR91) Express Lanes in Orange County, California in 1995 and since then, numerous HOT lane projects have been either implemented or are being considered for implementation in several metropolitan areas including California, Texas, Minnesota, Arizona, Colorado, and Virginia (Li, 2001). In Atlanta, the I-85 corridor contains a HOT lane.

Many studies and methodologies have been conducted in multiple aspects on optimizing HOV/HOT system effectiveness, including choice modeling (Burris & Xu, 2006), effect on total delay (Dahlgren, 2002) and the effect on emission (Boriboonsomsin & Barth, 2011). For HOT facilities, most studies focused on tolling strategies (Yin & Lou, 2009) (Lou, Yin, & Laval, 2011) and quantifying the willingness to pay (Small, Winston, & Yan, 2005). For most these studies, one of the key inputs is the commute time difference on the HOT/HOV versus on the general-purpose lanes. Surprisingly, there have been few empirical studies and agency reports that focus on HOV/HOT time reduction. The QuikRide program on the Katy Freeway in Houston collected manual counts of users for two days before implementation and seven days after implementation. The report, however, did not provides details about the data collection (Hickman, Brown, & Miranda, 2000). In a report from Minnesota Department of Transportation on I-394 MnPASS HOT facility, it is stated that the agency calculates timesavings through a detailed technical evaluation, but the report also did not provide details (HALVORSON & BUCKEYE, 2006). It is also worth noting that none of these studies used before and after data to assess changes in household travel behavior and door-to-door commute times (Smith, 2011).

Official guidelines about HOV/HOT design point out that travel time reduction remains a major factor in incentivizing HOV/HOT usage and should be considered a top planning objective (Turnbull, 1992) (Perez & Sciara, 2002). It is thus crucial for agencies to be able to estimate accurate timesavings when considering future construction of HOV/HOT facilities. This and the aforementioned inability to assess door-to-door commute times underscore the need to develop a reliable method that quantifies commute times on managed lanes and general purpose lanes.

CHAPTER 3. METHODOLOGY

Most route planning systems used in transportation logistics employ shortest path algorithms. For this project, the authors apply the RoadwaySim shortest path routines, developed by the Georgia Tech research team for a Department of Energy Project. The Python-based programs use a roadway network graph, with a variety of assigned attributes (such as link length, average speed, etc.) assigned to every roadway link in space and time, to predict the shortest path through the network graph from any origin latitude and longitude to any destination latitude and longitude.

To conduct a before and after travel time analysis of a managed lane facility, this study develops a straightforward method of running the shortest path algorithms twice, one for pre-condition input and once for post-condition input. The origin-destination pairs (O-D pairs) of the trips remain the same in both model runs, so that model outputs will be comparable. A flowchart of this process is shown in Figure 2 (explained in detail for the NWC managed lane case study in Chapter 4).

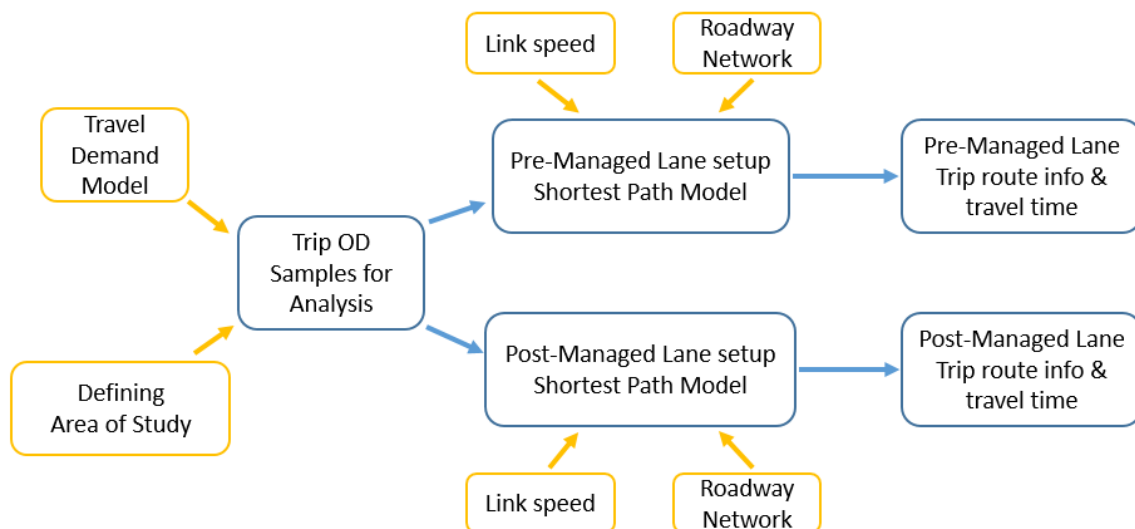


Figure 2. Analytical Method Workflow

3.1 Shortest Path Algorithm - RoadwaySim by Georgia Tech

In 2017, Georgia Tech researchers developed a multi-modal Python-based routing platform called “Commute Alternatives,” designed to identify the optimal commute multi-modal option, route, and departure time for any origin-destination (O-D) pair (in space and time) for the Atlanta Metropolitan Region. The platform consists of the RoadwaySim and TransitSim modules, each with the routing, energy and cost calculating functions. TransitSim provides the second inter-connected layer to the modeling suite, allowing the shortest path routine to include bus and rail transit service. Simulated travelers can leave the roadway graph, enter the transit graph and follow a bus or train schedule, and then return to the roadway graph. This allows transit and park and ride options to be included for multi-modal shortest path identification. The routing module generates commute alternatives for an input origin and destination pair, an input trip departure time, and a target arrival time (Li, et al., 2018). In its most recent version, the platform imports the 203,000 link (203k link) roadway link network shape file provided by the Atlanta Regional Commission (ARC). The platform is also capable of storing and calculating routes based on dynamic speeds. That is, the routines can traverse through the network in space and time. The platform currently uses the outputs from a 15-minute Dynamic Traffic Assignment (DTA) model outputs applied to all 203k links within the network over a typical one-day modeling period. Researchers at Southern Methodist University provided the DTA outputs for an ARPA-E project. The platform is scripted in Python, providing users with the flexibility of changing the network, traffic inputs, link speeds, and origin-destination pairs. This study uses the RoadwaySim module within Commute Alternatives for the shortest path analysis, based on its flexibility for user inputs and integration of DTA outputs. Because this paper

focuses on the timesavings before and after the opening of managed lane facility, the energy and cost calculations are not reported for this analysis.

The RoadwaySim routines output the optimal (fastest) route for every O-D input. The output consists of csv files with detailed information including the name and number of each link in the route and the time spent to traverse each link. Using Excel functions, the total travel time of each trip was summarized. The output also includes the route geometry jpg file for every O-D input. For a before-and-after analysis, the shortest path algorithm recalculates the optimal route based on the before-and-after link speeds. As a result, for some O-D pairs, the route change can be quite significant, as shown below in Figure 3.

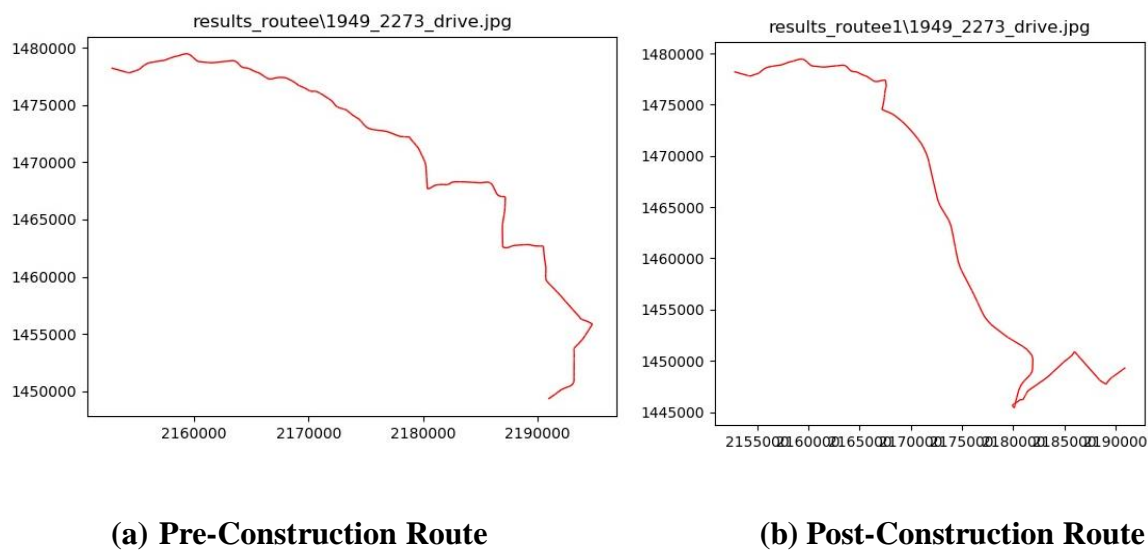


Figure 3. Example of Pre (a) and Post (b) NWC Managed Lane Construction Shortest Path Route Comparison (TAZ #1949 to TAZ #2273)

CHAPTER 4. RESEARCH SCENARIO PARAMETERS

4.1 Defining the Study Area

This study applies the method in Chapter 3 to evaluate the before-and-after timesavings on the NWC managed lane facility in Atlanta, Georgia. The NWC managed lanes span 26.4 miles along sections of I-75 and I-575, however, not all residents within the same vicinity use the facility. Identifying the primary users of the NWC managed lanes is the first task for this case study. This study adopts Traffic Analysis Zones (TAZ) from the Atlanta Regional Commission's (ARC's) activity-based model (ABM) as base units for all trip origins and destinations, and applies two criteria to filter out the TAZs where most residents use the NWC managed lane facility.

4.1.1 The Commutershed

The concept of a “commutershed” or “catchment area” has been employed in previous studies to estimate travel demand for new and existing facilities (Horner & Groves, 2007). For the Atlanta metro area, Khoeini (Khoeini, 2014) created a visualization of the I-85 managed lane facility commutershed in 2014. Her paper draws a directional distribution ellipse that covers 95 % of the observed license plate origins collected in 2006 by Georgia Tech researchers. However, the research team has found that the I-75 corridor appears to serve commuters from a much wider region than I-85, making the 95% confidence ellipse much too large to capture the TAZs with most frequent users of the NWC managed lanes. This paper retains the rotation angle of the ellipse but contracts the ellipse proportionally until its southeastern tip meets the I-75/I-

285 interchange, where the NWC managed lanes start. This serves as the first criteria to filter out the origin TAZs for the shortest path routing analysis.

4.1.2 License Plate Origin Zip Codes

Since fall 2018, Georgia Tech researchers has been actively involved in the “Vehicle Occupancy, Vehicle and Person Throughput, and Carpooling Demographics of SRTA’s Managed Lane” Project (Georgia Tech Center for Transportation Research, 2018). Crews were dispatched to collect vehicle occupancy and record license plate data at five sites for at least five weekdays each along SRTA’s manage lane facilities. The team deployed to two NWC managed lane locations (Hickory Grove Road @ I-75 and Chastain Road @ I-575) and collected over 100,000 license plates at these two sites. Of these, 62,807 plates were matched with registration zip code of each registered vehicle owner’s residence (for privacy protection, addresses are not employed). This study identified the 10 zip codes with the highest number of NWC managed lane user residences. These zip codes contribute about 45% of the matched plates. These zones are all concentrated north of the I-75 and I-575 split. The team then identified all travel demand model transportation analysis zones (TAZs) that are **both** within the directional ellipse mentioned above, and within the 10 zip codes. By using the selection-by-location function in ArcMAP 10.6, the study identifies 255 TAZs that serve as the origins for the trips that will be analyzed for this study. The locations of the 255 TAZs and both filtering criteria are shown in Figure 4 (the NWC managed lane facility is shown in Purple).

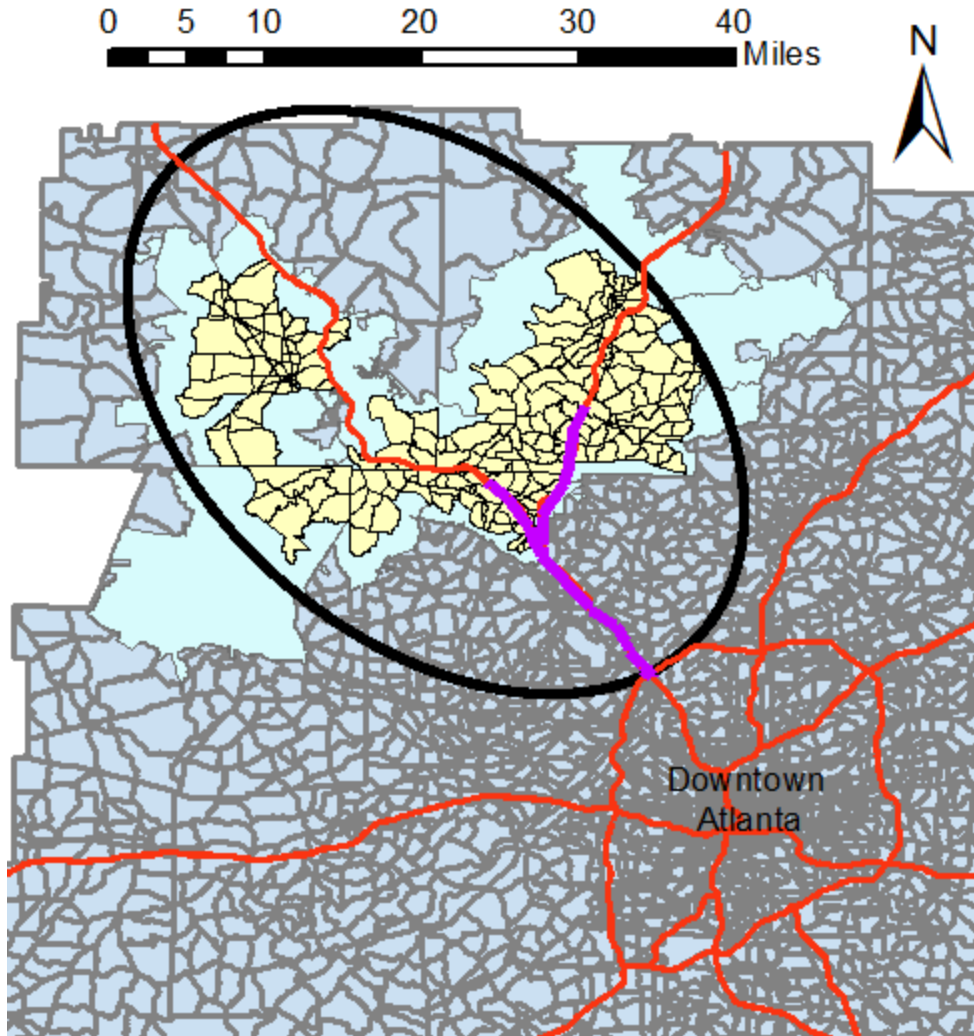


Figure 4. The 255 TAZs Identified as Trip Origins (in yellow), Commutershed Directional Ellipse (in Black), and Top 10 License Plate Zip Codes (in Green).

4.2 Trip Sampling from the Activity Based Model

This study uses the trip table outputs from the ARC's ABM for their calendar year 2020 model run (Atlanta Regional Commission, 2018). The ABM has the capability to predict in detail the trip characteristics such as mode, trip purpose and departure time for every trip that leaves from /arrives at any of the 5,873 TAZs within the 20-county metro Atlanta region. The

2020 ABM predicts that the 255 previously identified TAZs generate more than 200,000 trips between 6:30 to 8:30AM on a typical weekday, which would include work trips, school trips, shopping trips, etc. The study then uses the following filtering criteria on three trip attributes to narrow down the search to the actual commute trips:

- Trip Purpose (Dest_purpose): “work” or “university” trips
- Travel distance: larger than 10 miles, to focus on long distance commute trips
- Travel Mode (Trip_mode): eliminate all transit, walk and bike modes

Using these criteria, 29,793 unique O-D pairs were sampled, covering 32,174 trips. A detailed number of O-D pairs and number of trips for each time period are shown below in Table 1.

Table 1. ABM trip results for each time period from 6:30 AM-8:30 AM

		6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	TOTAL
NWC Managed Lane Users	Unique O-D Pairs	1,253	1,425	1,049	801	4,528
	Number of Trips	1,318	1,526	1,099	821	4,764
NWC GP Lane Users	Unique O-D Pairs	6,756	7,897	5,945	4,667	25,265
	Number of Trips	7,282	8,716	6,451	4,961	27,410

4.3 Model Input Setup

4.3.1 Roadway Network

The study uses the 203k link roadway network provided by the ARC (already in place in the RoadwaySim module for the pre-construction scenario). For the post-construction scenario, 98 NWC managed lane links (including the managed lane links, merge links, and dedicated on-ramps) were manually added through ArcMAP 10.6 into the 203k link network. An example of

this is shown in Figure 5. The added links were carefully coded to match the naming convention in the old 203k link network, so that the shortest path algorithm can use the new links.

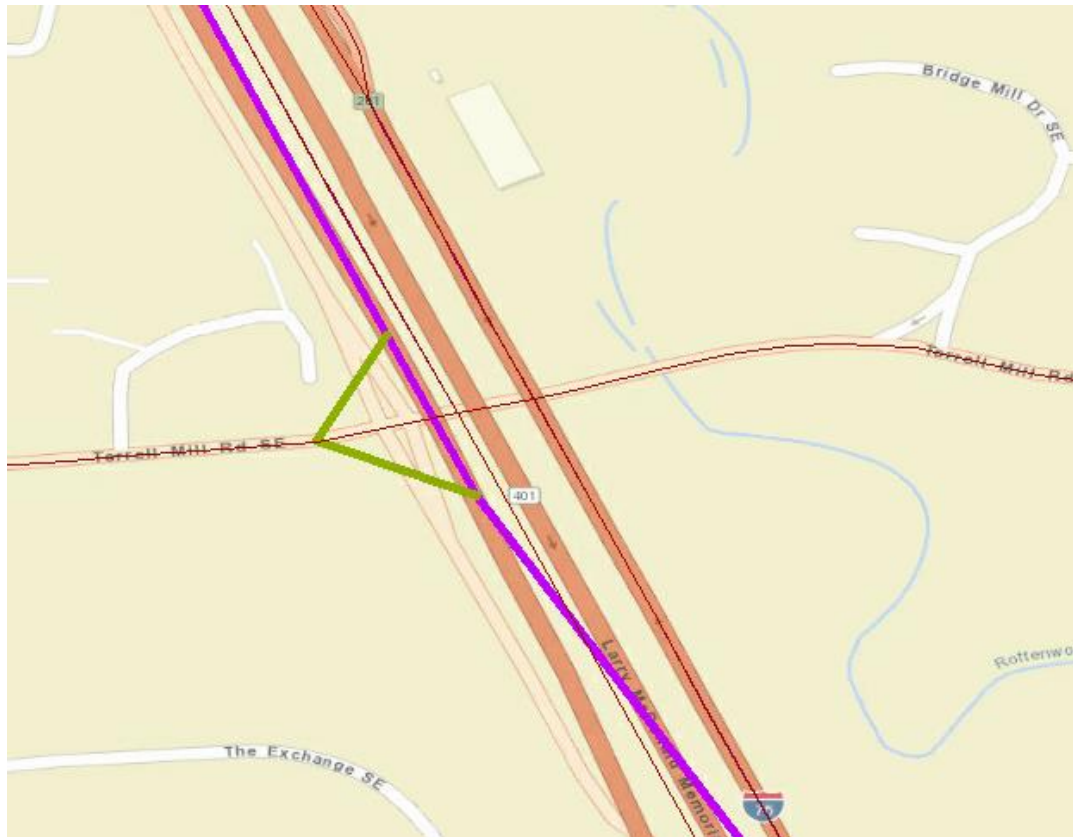


Figure 5. 98 NWC Managed Lane Links Added to the Existing 203k Link Roadway Network (Purple Segments Represent the Managed Lane and Green Segments Represent the On-Ramps)

4.3.2 Link Speed

For the pre-construction scenario, the study uses the 15-minute DTA outputs that were already in place in RoadwaySim for all the arterial and local road speeds. For the I-75 and I-575 General Purpose (GP) lane speeds, the study imported NaviGator data provided by GDOT to pursue a more accurate speed assignment. The freeway speed data were obtained by GDOT's speed camera set along I-75 and I-575. The study uses data from March 2018 to represent pre-

construction speed for the GP lanes, and focus on the cameras located within the 26.4-mile NWC managed lane sections. GP lane speed in pre-construction period shows a significant dip in average speed to below 45mph from 7:15 to 7:45 A.M. Some link speeds fall below 25mph. The average speed then gradually climbs up to above 50 mph after 8:30 A.M. For the post-construction GP speed data, April 2019 data were used to represent post-construction GP speed. It shows significant speed improvement after the managed lanes were opened. The average speed from 6:30 to 10:00 A.M. stays consistently above 50mph, although one section still recorded speed of under 25mph. The mile markers of the NaviGator cameras were provided and were used to match the speed data through ArcMAP 10.6 to their corresponding links in the 203k link network.

As for the NWC managed lane speeds in the post-construction period, the study employs SRTA's own observed speed data from their tolling points in April 2019. The managed lanes speed data indicate a consistent high traffic speed that ranges from 60 mph to 75 mph from 6:30 to 10:00 A.M., with an average speed of 66.4mph on the corridor. Similar to the NaviGator data, the mile markers of the tolling points were used to match the speed to the corresponding 98 NWC managed lane links.

Because all modeled trips start and end at the centroid of a TAZ, rather than on a major roadway link, RoadwaySim applies centroid connector travel times to each end of the trip. These travel times are based upon a centroid connector length and an ARC-assumed speed of 11 mph, according to ARC's ABM free flow speed table for centroid connectors in suburban area TAZs (WSP | Parsons Brinckerhoff, Atkins, 2017). RoadwaySim identifies the link closet to the origin to start the trip and adds the centroid connector travel time from road to TAZ centroid (the

same process is used at the destination end). The speeds for all ramps and merge links in the NWC facility are assumed to be 50 mph, based on the same ABM free flow speed table.

4.3.3 Trip O-D input

As mentioned in the beginning of this section, this study uses TAZs as base units for all trip origins and destinations. Trips are assumed to start from the centroid of the origin TAZ and travel to the centroid of the destination TAZ. The model inputs are the latitude and longitude of the TAZ centroids. For each O-D pair there can be more than one trip; for this analysis, the 29,793 O-D pairs account for 32,174 trips, which means on average each O-D pair has 1.08 trips (the vast majority of O-D pairs only have one trip). A detailed number of O-D pairs and number of trips for each time period are shown below in Table 1. It should be noted again that the input to the shortest path algorithm are the TAZ centroids of each O-D pair. For the remainder of this paper, O-D pairs, rather than number of trips, will be used to discuss the results for travel timesavings.

All 9,323 O-D pairs were processed as inputs in the pre-construction shortest path model run. The 2020 ABM predicts that out of the 9,323 (10,245 trips) unique O-D pairs, 1,425 O-D pairs (1,526 trips) will pay the toll to use the NWC facility. As a result, the post-construction shortest path model run were performed in two stages: the 1,425 O-D pairs were processed with the new 203k+98 NWC managed lane links network, with updated speed for the GP lanes and the managed lanes. The rest of the 7,898 O-D pairs were processed with the old 203k link network, with only the updated speeds in the GP lanes. Table 2 below further explain this setup.

Table 2. Shortest Path Model Input for Pre and Post-Construction Managed Lane (ML) Scenarios (32,174 Trip Subset)

Scenario	Input O-D	Roadway Network	Link Speed Data Source
Pre-Managed Lanes	25,265 O-D Pairs (GP)	203k link network	<ul style="list-style-type: none"> • Arterials : DTA speed • GP Lanes: 2018 NaviGator data
	4,528 O-D Pairs (GP)	203k link network	<ul style="list-style-type: none"> • Arterials : DTA speed • GP Lanes: 2018 NaviGator data
Post-Managed Lanes	25,265 O-D Pairs (GP)	203k link network	<ul style="list-style-type: none"> • Arterials : DTA speed • GP Lanes: 2019 NaviGator data
	4,528 O-D Pairs (ML)	203k link network + 98 NWC managed lane links	<ul style="list-style-type: none"> • Arterials : DTA speed • GP Lanes: 2019 NaviGator data • NWC Managed lanes: SRTA speed data

CHAPTER 5. CORRIDOR COMMUTE TIMESAVINGS

As described in Chapter 4, the post-construction managed lane speeds are about 20 mph higher than the pre-construction general purpose lane speed. As expected, major timesavings accrue to NWC managed lane users. However, the managed lanes also result in an improvement in general purpose lane speeds. The post-construction general purpose lane speed is about 8 mph higher than the pre-construction speed; hence, timesavings are also expected for the general purpose lane users. The following sections discuss the timesavings for trips that leave within 6:30-7:00 A.M., 7:00-7:30 A.M., 7:30-8:00 A.M., and 8:00-8:30 A.M. It is assumed in the research that all trips are completed within 2 hours, so for each departure period, 15-minute DTA speeds were loaded into the 203k link network links for the next 120 minutes (e.g., for the 6:30-7:00 period, speeds were loaded from 6:30-8:30 A.M.; for the 8:00-8:30 period speeds were loaded from 8:00-10:00 A.M.).

The pre and post NWC managed lane construction travel time differences in the four periods are obtained directly from the shortest path algorithm, and are aggregated for the trips assessed to get the average time savings for the time period. Total vehicle-hours for the 32,174 trips assessed were calculated by multiplying the time difference of each O-D with its corresponding number of trips in the ABM output. The total person-hours were also calculated by multiplying the time difference of each O-D with its corresponding number of trips **and** the **occupancy** of each O-D (the occupancy of each O-D is obtained by summing up the occupancy value per vehicle that travels that O-D), which is also an output of the ABM.

Collectively, the NWC facility saves **1138.8 vehicle-hours (1477.9 person-hours) for NWC managed lane users**, and **1208.9 vehicle-hours (1533.7 person-hours)** for general

purpose lane users for the 32,174 trips assessed. It is noteworthy that general purpose lane users are modeled as saving more total travel time than the managed lanes users, in both vehicle-hours and person-hours, but each general purpose lane user saves a much smaller amount of time. The detailed breakdown of timesavings per 30-minute period are as follows:

5.1 6:30 A.M. -7:00 A.M.

5.1.1 NWC Managed Lane Users Timesavings

The ABM predicts that 1,253 unique O-D pairs are going to pay and use the facility from 6:30-7:00 A.M. (routes were calculated for 1,218 of these O-D pairs). The average commute time before managed lane construction is 54.6 minutes, which dropped to 43.1 minutes after managed lane construction. This results in an average **21.0%** timesavings for these trips. The median travel time also dropped from 53.8 minutes to 42.1 minutes. A frequency distribution map is shown below in Figure 6. The peak commute time shifts significantly to the left, indicating the timesavings for the NWC managed lane users. The subset of NWC managed lanes users examined in this time period save **244.9 vehicle-hours (276.5 person-hours)**.

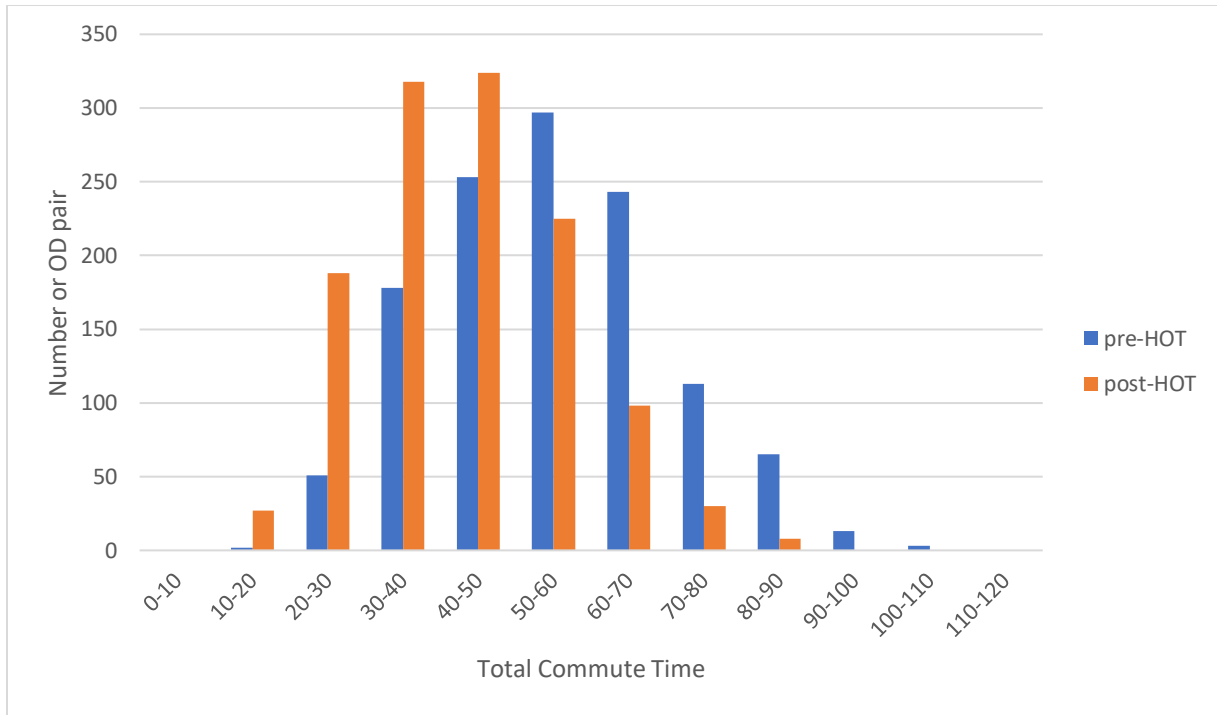


Figure 6. NWC Managed Lane Users Timesavings from 6:30 - 7:00 A.M.

5.1.2 General Purpose Lane User Timesavings

The ABM predicts travel between 6,756 unique O-D pairs departing between 07:00 and 07:30 A.M. (routes were calculated for 6,513 O-D pairs). Further processing of the routing results in Excel found that out of these O-D pairs, 4,465 O-D pairs would use the general purpose lanes. The vehicles on the GP lanes also experience timesavings. For the 4,465 O-D pairs, the average commute time pre-construction is 48.6 minutes, which drops to 43.5 minutes in post-construction scenario. This results in an average **10.6%** timesavings for these trips. The median travel time also dropped from 47.2 minutes to 41.7 minutes. A frequency distribution map is shown below in Figure 7. The shift in peak is not as obvious as the managed lane user results, but a significant amount of commutes that were over 60 minutes shifted left and are now within 60 minutes, due to the improvement to the general purpose lanes caused by the managed

lanes. The subset of NWC general purpose lane users examined in this time period save **381.7 vehicle-hours (465.8 person-hours)**.

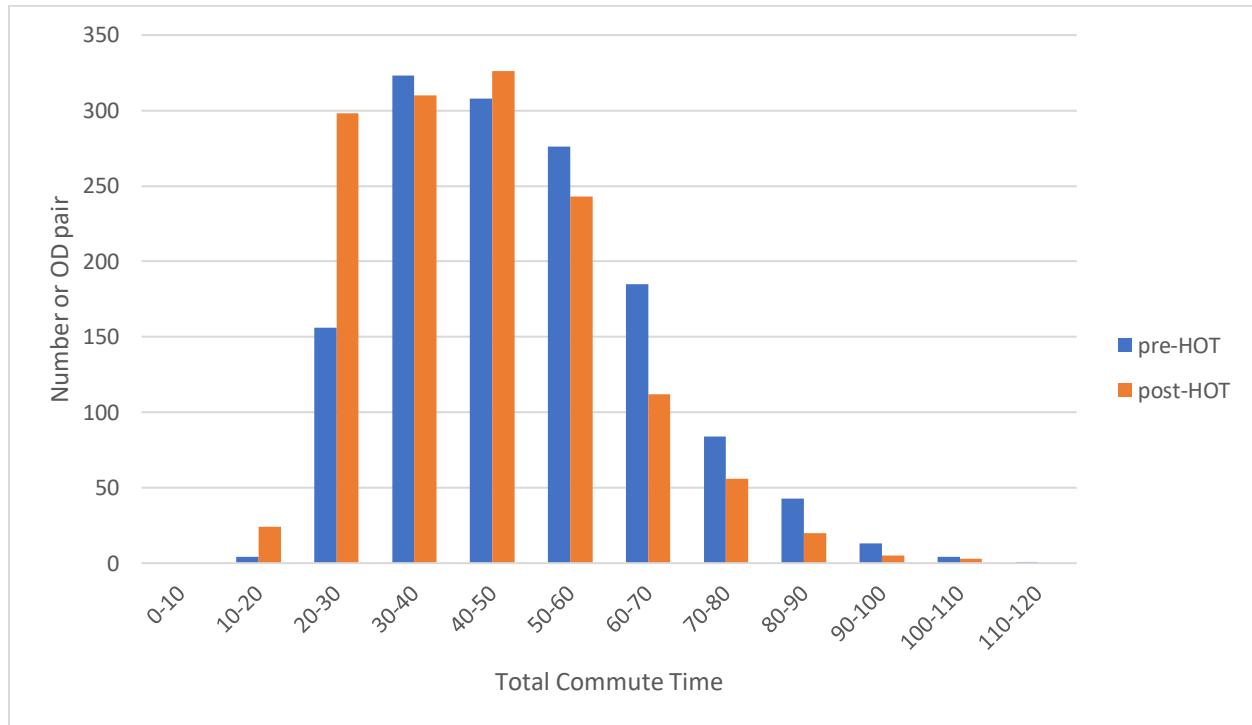


Figure 7. General Purpose Lane User Timesavings from 6:30 - 7:00 A.M.

5.2 7:00 A.M. - 7:30 A.M.

5.2.1 NWC Managed Lane User Timesavings

The ABM predicts that 1,425 unique O-D pairs are going to pay and use the managed lane facility from 7:00-7:30 A.M. (routes were calculated for 1,397 O-D pairs). The average commute time pre-managed lanes is 59.8 minutes, which dropped to 43.5 minutes in the post-managed lanes scenario. This results in an average **27.1%** timesavings for these trips. The median travel time also dropped from 59.7 minutes to 42.6 minutes. A frequency distribution map is shown below in Figure 8. The peak commute time shifts significantly to the left,

indicating the timesavings for managed lanes users. The subset of NWC managed lanes users examined in this time period save **402.7 vehicle-hours (449.4 person-hours)**.

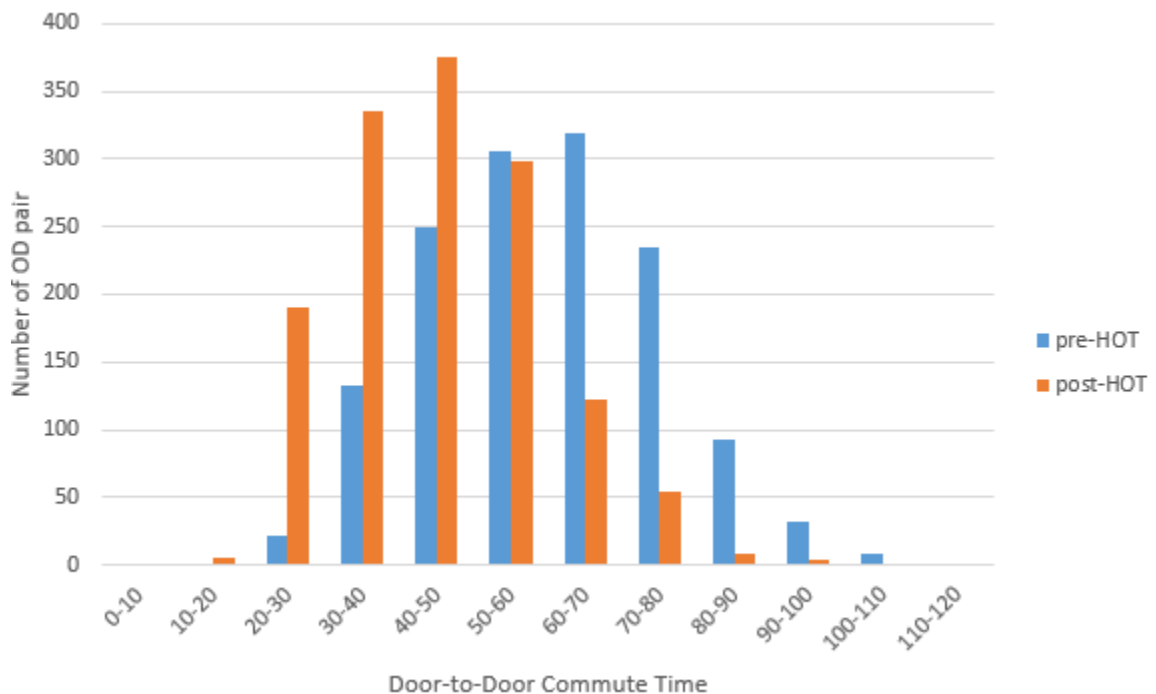


Figure 8. NWC Managed Lane Users Timesavings from 7:00 - 7:30 A.M.

5.2.2 General Purpose Lane User Timesavings

The ABM predicts that 7,897 unique O-D pairs departing between 07:00 and 07:30 A.M. (routes were calculated for 7,608 O-D pairs). Further processing of the routing results in Excel found that out of these O-D pairs only 4,678 would take the general purpose lane and would experience timesavings. For these O-D pairs, the average commute time pre-construction is 50.4 minutes, which drops to 44.4 minutes in post-construction scenario. This results in an average **12.0%** timesavings for these trips. The median travel time also dropped from 50.2 minutes to 43.6 minutes. A frequency distribution map is shown below in Figure 9. The shift in peak is not

obvious as the managed lane user results, but a significant amount of commutes that were over 60 minutes shifted left and are now within 60 minutes due to the improvement to the general purpose lanes caused by the NWC managed lanes. The subset of NWC general purpose lane users examined in this time period save **388.8 vehicle-hours (482.7 person-hours)**.

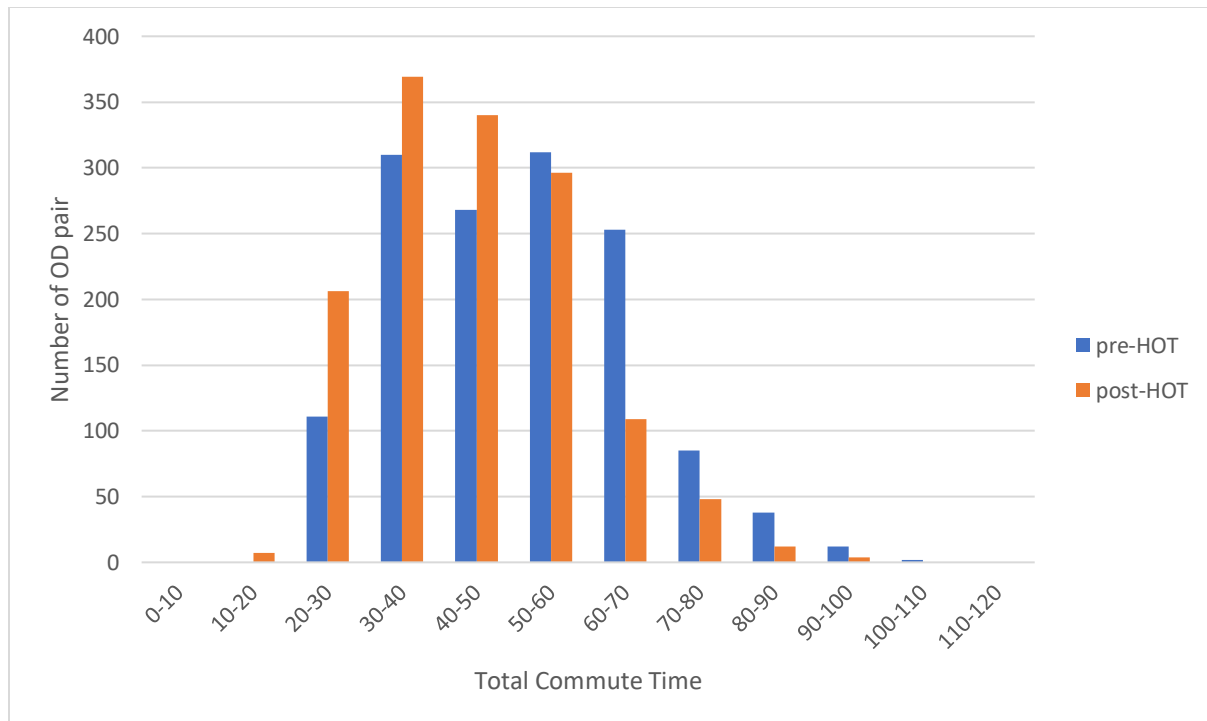


Figure 9. General Purpose Lane User Timesavings from 7:00 - 7:30 A.M.

5.3 7:30 A.M. - 8:00 A.M.

5.3.1 NWC Managed Lane Users Timesavings

The ABM predicts that 1,049 unique O-D pairs are going to pay and use the managed lane facility from 7:30-8:00 (routes were calculated for 1,024 of these pairs). The average commute time pre-construction is 58.8 minutes, which dropped to 43.0 minutes in the post-construction scenario. This results in an average **26.9%** timesavings for these trips. The median

travel time also dropped from 58.6 minutes to 42.2 minutes. A frequency distribution map is shown below in Figure 10. The peak commute time shifts significantly to the left, indicating the timesavings for managed lane users. The subset of NWC managed lanes users examined in this time period save **281.8 vehicle-hours (316.8 person-hours)**.

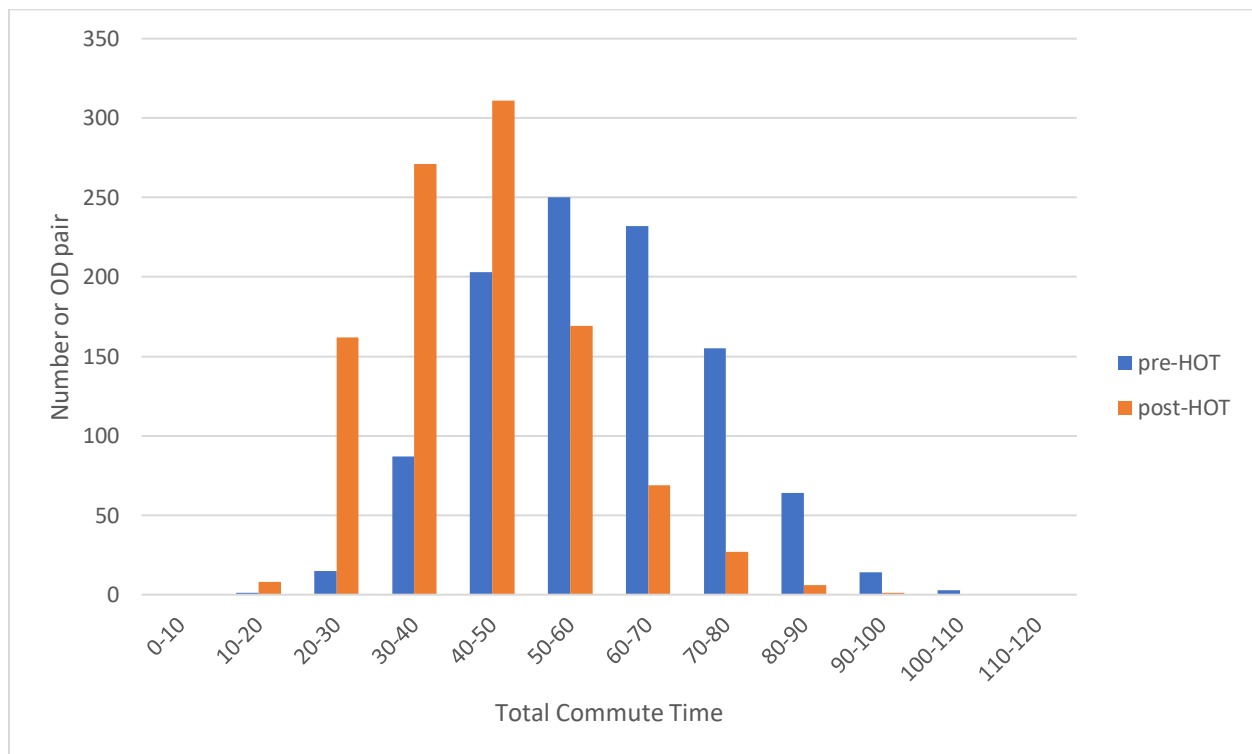


Figure 10. NWC Managed Lane Users Timesavings from 7:30 – 8:00 A.M.

5.3.2 General Purpose Lane User Timesavings

The ABM predicts that 5,945 unique O-D pairs departing between 07:30 and 08:00 A.M. (routes were calculated for 5,739 O-D pairs). Further processing of the routing results in Excel found that out of these O-D pairs only 3,818 would take the general purpose lane and would experience timesavings. For these O-D pairs, the average commute time pre-construction is 51.7

minutes, which drops to 47.8 minutes in post-construction scenario. This results in an average **7.7%** timesavings for these trips. The median travel time also dropped from 50.0 minutes to 45.8 minutes. A frequency distribution map is shown below in Figure 11. The shift in the peak is not obvious as the managed lane user results, but a significant number of commutes that were over 60 minutes shifted left and are now within 60 minutes due to the improvement to the general purpose lanes caused by the NWC managed lanes. The subset of NWC general purpose lane users in this time period save **286.3 vehicle-hours (345.6 person-hours)**.

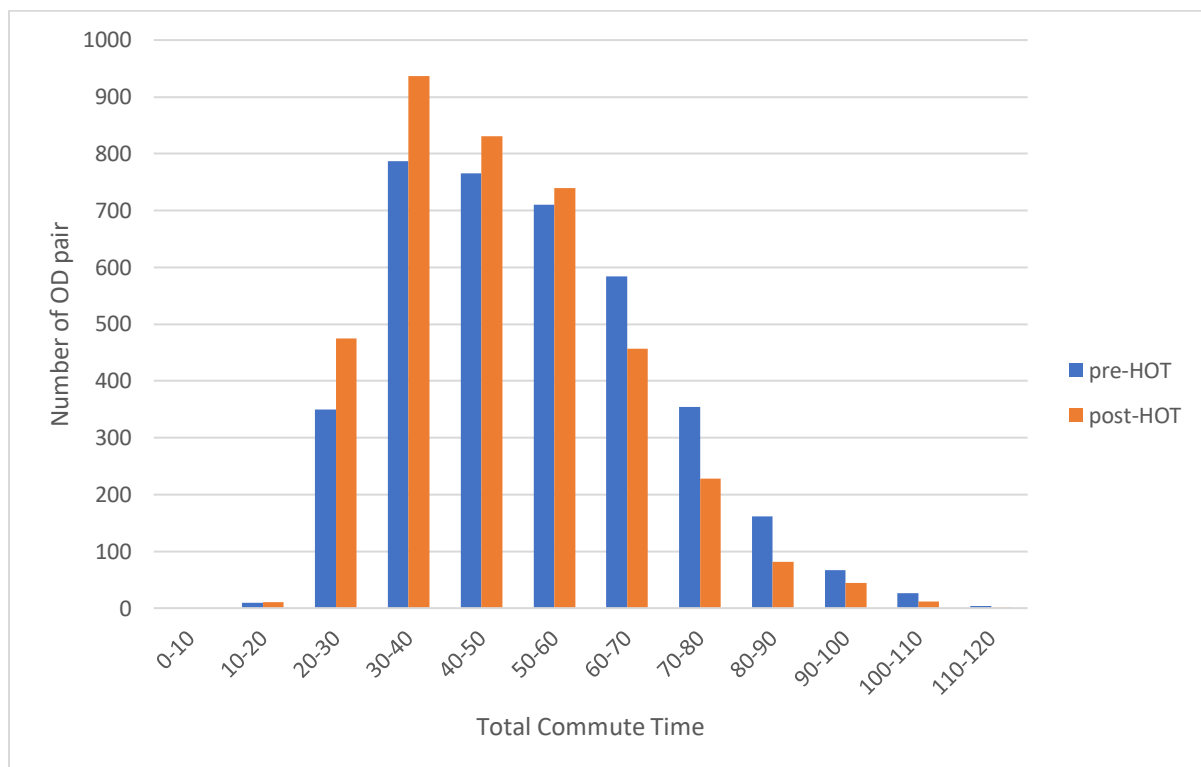


Figure 11. General Purpose Lane User Timesavings from 7:30 - 8:00 A.M.

5.4 8:00 A.M. - 8:30 A.M.

5.4.1 NWC Managed Lane Users Timesavings

The ABM predicts that 801 unique O-D pairs are going to pay and use the facility from 7:30-8:00 A.M. (routes were calculated for 799 of these pairs). The average commute time pre-construction is 57.5 minutes, which dropped to 42.5 minutes in the post-construction scenario. This results in an average **26.1%** timesavings for these trips. The median travel time also dropped from 56.6 minutes to 40.5 minutes. A frequency distribution map is shown below in Figure 12. The peak commute time shifts significantly to the left, indicating the timesavings for NWC managed lane users. The subset of NWC managed lanes lane users examined for this time period save **209.4 vehicle-hours (239.6 person-hours)**.

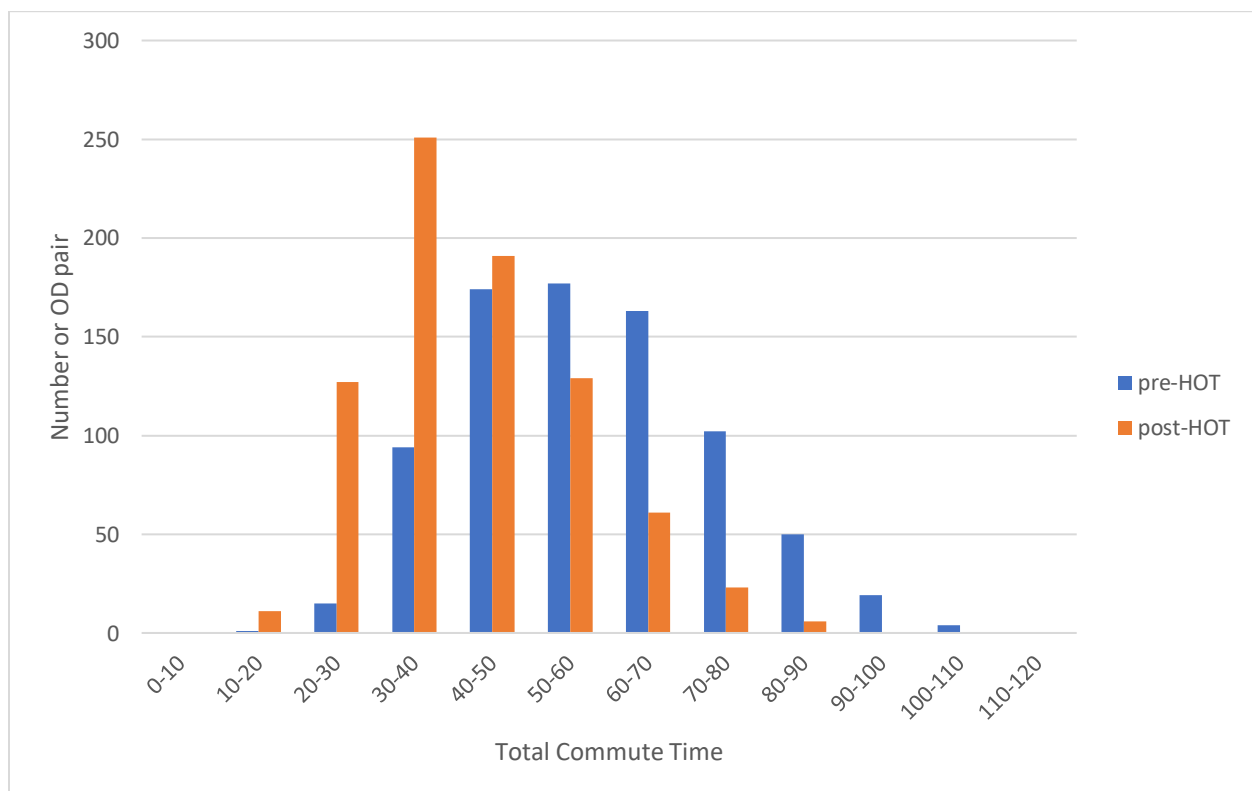


Figure 12. NWC Managed Lane Users Timesavings from 8:00 – 8:30 A.M.

5.4.2 General Purpose Lane User Timesavings

The ABM predicts that 4,667 unique O-D pairs departing between 08:00 and 08:30 A.M. (routes were calculated for 4,491 of these pairs). Further processing of the routing results in Excel found that only 2,914 O-D pairs would take the general purpose lane and would experience timesavings. For these O-D pairs, the average commute time pre-construction is 50.1 minutes, which drops to 47.2 minutes in post-construction scenario. This results in an average **5.8%** timesavings for these trips. The median travel time also dropped from 46.9 minutes to 44.4 minutes. A frequency distribution map is shown below in Figure 13. The shift in the peak is not obvious as in the NWC managed lane user results, but a significant amount of commutes that were over 60 minutes shifted left and are now within 60 minutes due to the improvement to the general purpose lanes caused by the managed lanes. The subset of NWC general purpose lane users examined for this time period save **152.1 vehicle-hours (188.1 person-hours)**.

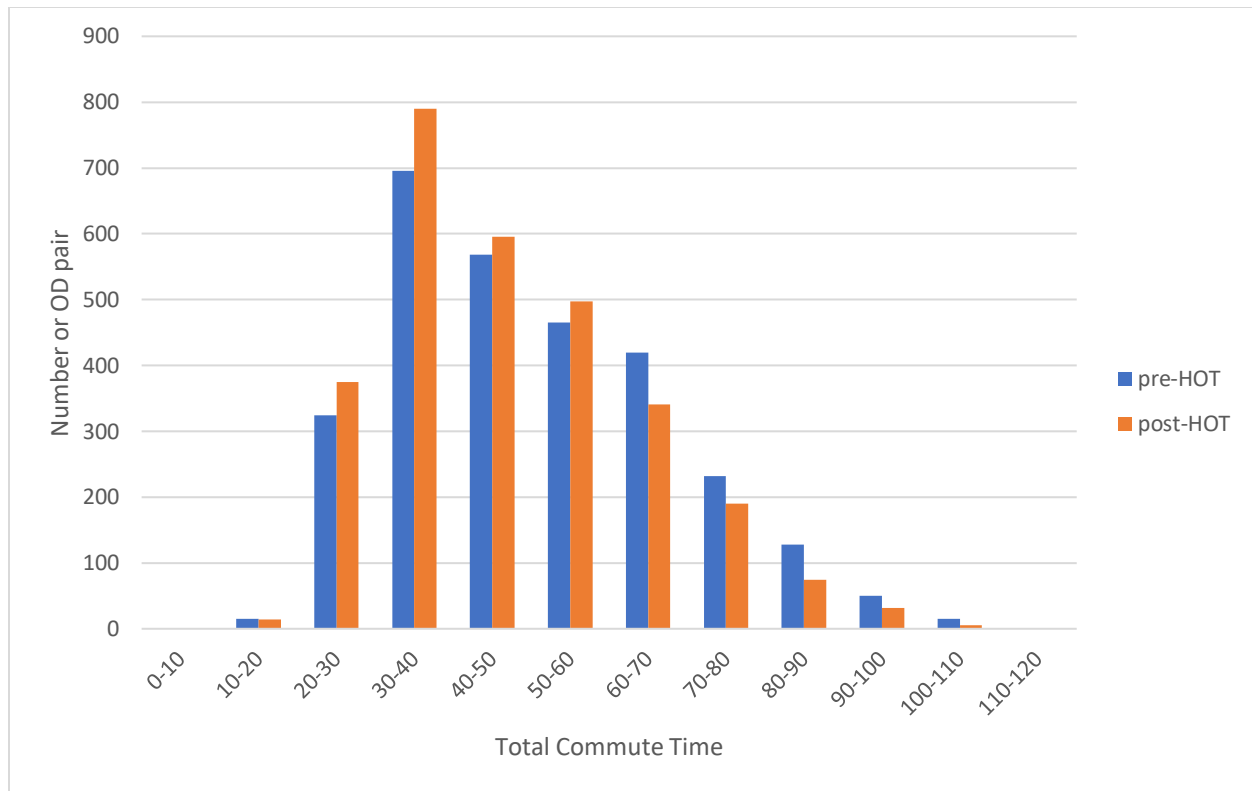


Figure 13. General Purpose Lane User Timesavings from 8:00 - 8:30 A.M.

5.5 Summary

For both NWC managed lane and general purpose lane users, the timesaving percentage of total travel time peaks at the 07:00-7:30 A.M. period, with the NWC managed lane at 27.1% and general purpose lane users at 12.0%. After 7:30 A.M., for NWC managed lane users the timesavings percentage stays above 25 percent, while the percentage drops for general purpose lane users after 7:30 A.M (Figure 14). The time minute savings follow the same trend, shown below in Figure 15.

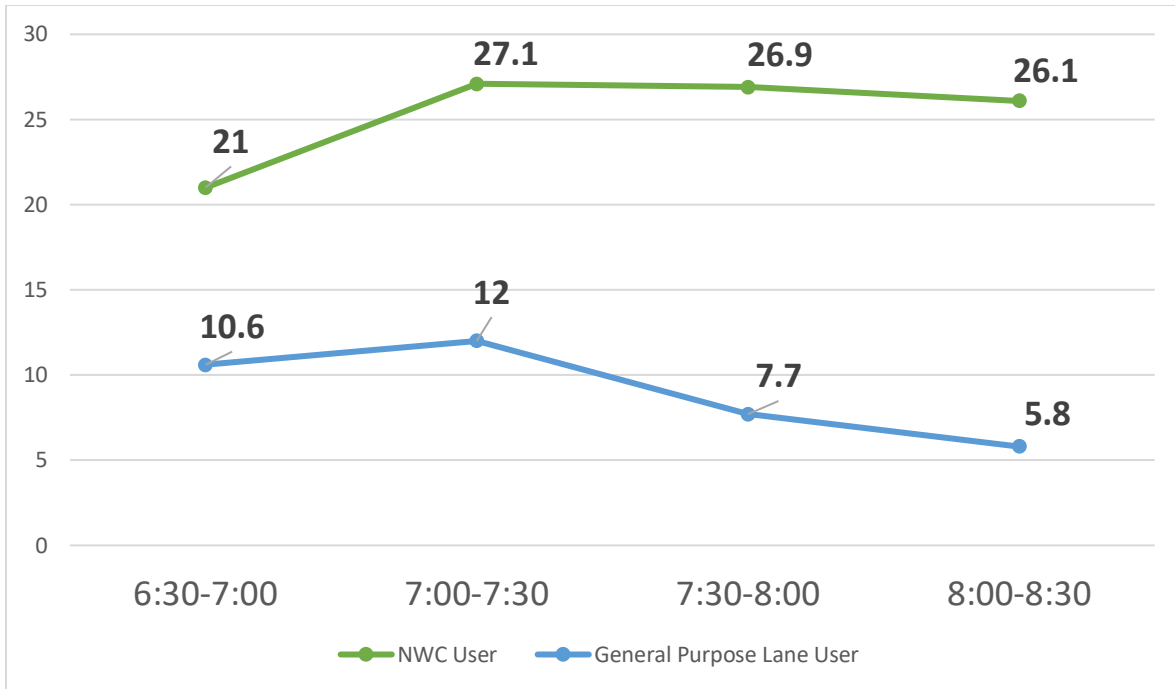


Figure 14. Travel Time Reduction (in Percent) from 6:30 - 8:30 A.M.

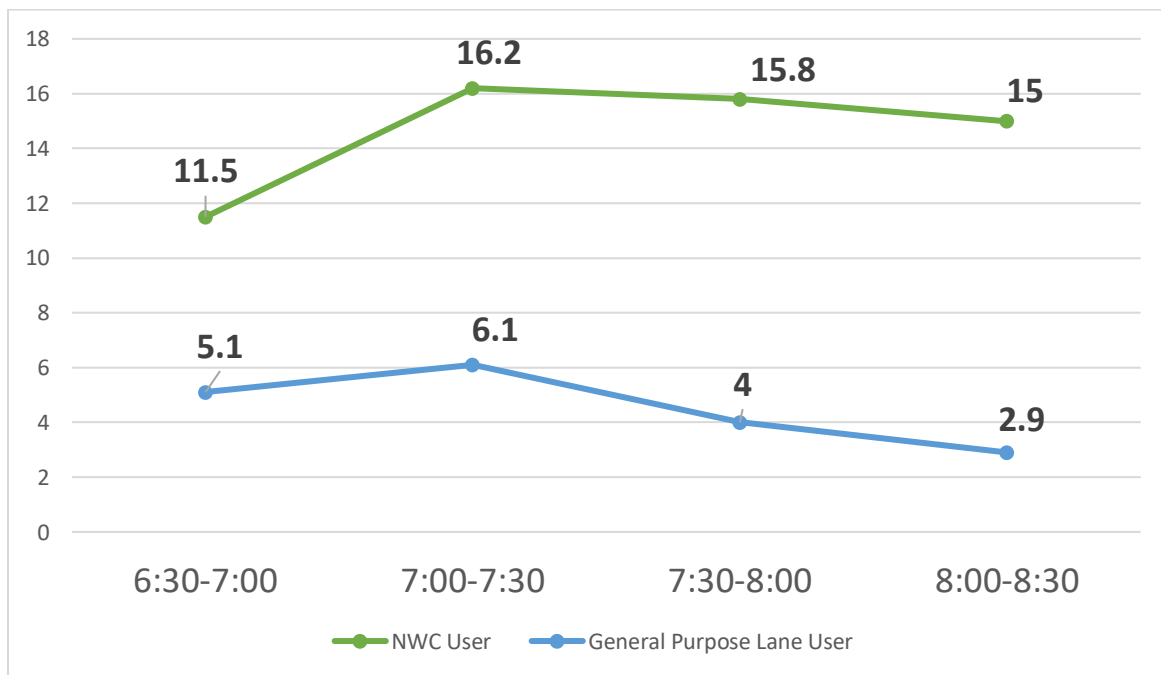


Figure 15. Travel Timesavings (in Minutes) from 6:30 - 8:30 A.M.

For the total vehicle-hours and person hours saved, both also peak at the 7:00-7:30 A.M. period, shown below in Figure 16 and Figure 17. Although it should be noted that the 7:00-7:30 A.M included the largest number of trips.

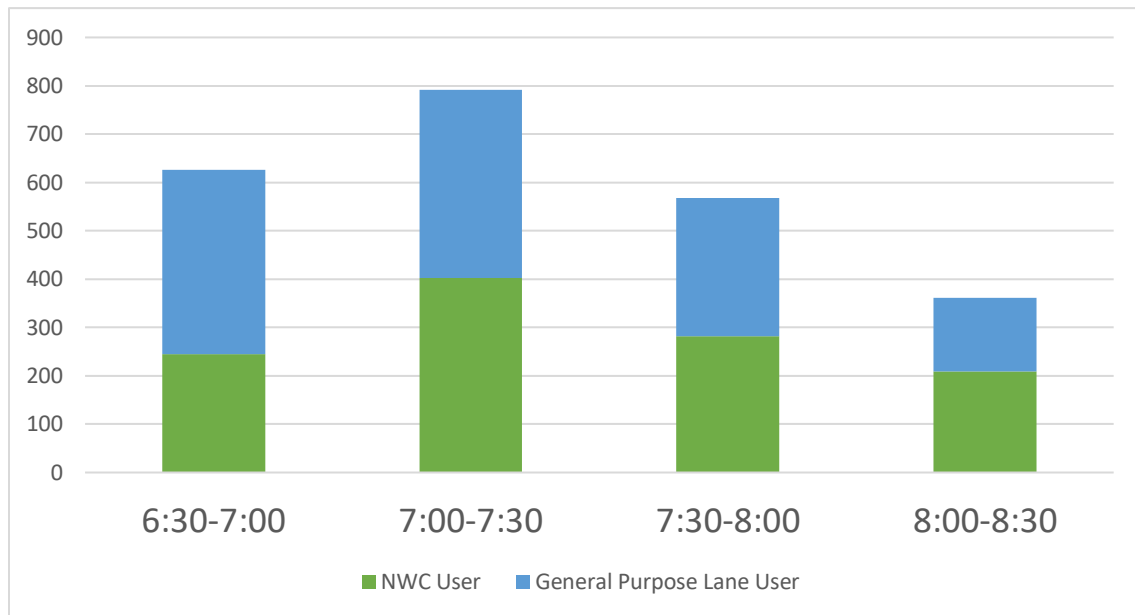


Figure 16. Vehicle-Hours Saved in each 30-minute period from 6:30 - 8:30 A.M.

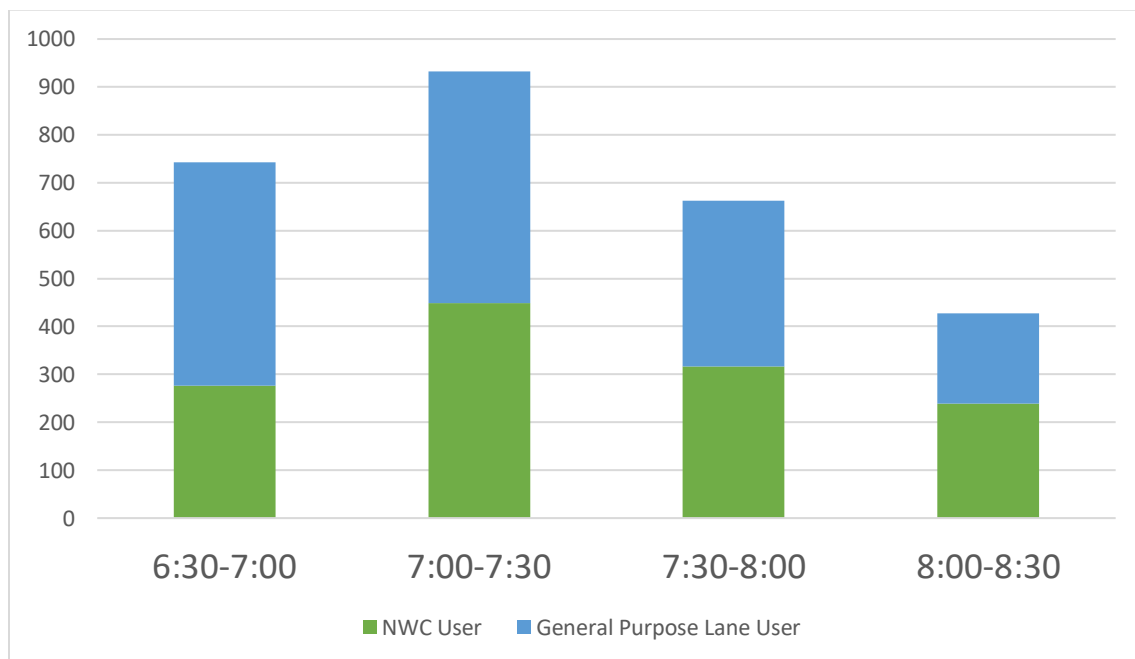


Figure 17. Person-Hours Saved in each 30-minute period from 6:30 - 8:30 A.M.

5.6 Spatial Analysis

From 6:30 to 8:30 A.M., the 32,174 trip subset of trips assessed in this study saved 2348 vehicle-hours (2765 person-hours). However, this does not shed light on the geographical distributions of these hour savings, i.e., whether or not some areas within the defined commutershed are experiencing more savings than the others. By associating the origin TAZ to the individual vehicle-hour and person-hour saved for the O-D, the hours saved for O-D pairs starting from each of the 255 origin TAZs can be aggregated. A map illustrating the vehicle-hours saved is presented Figure 18, and the person-hour map is shown below in Figure 19.

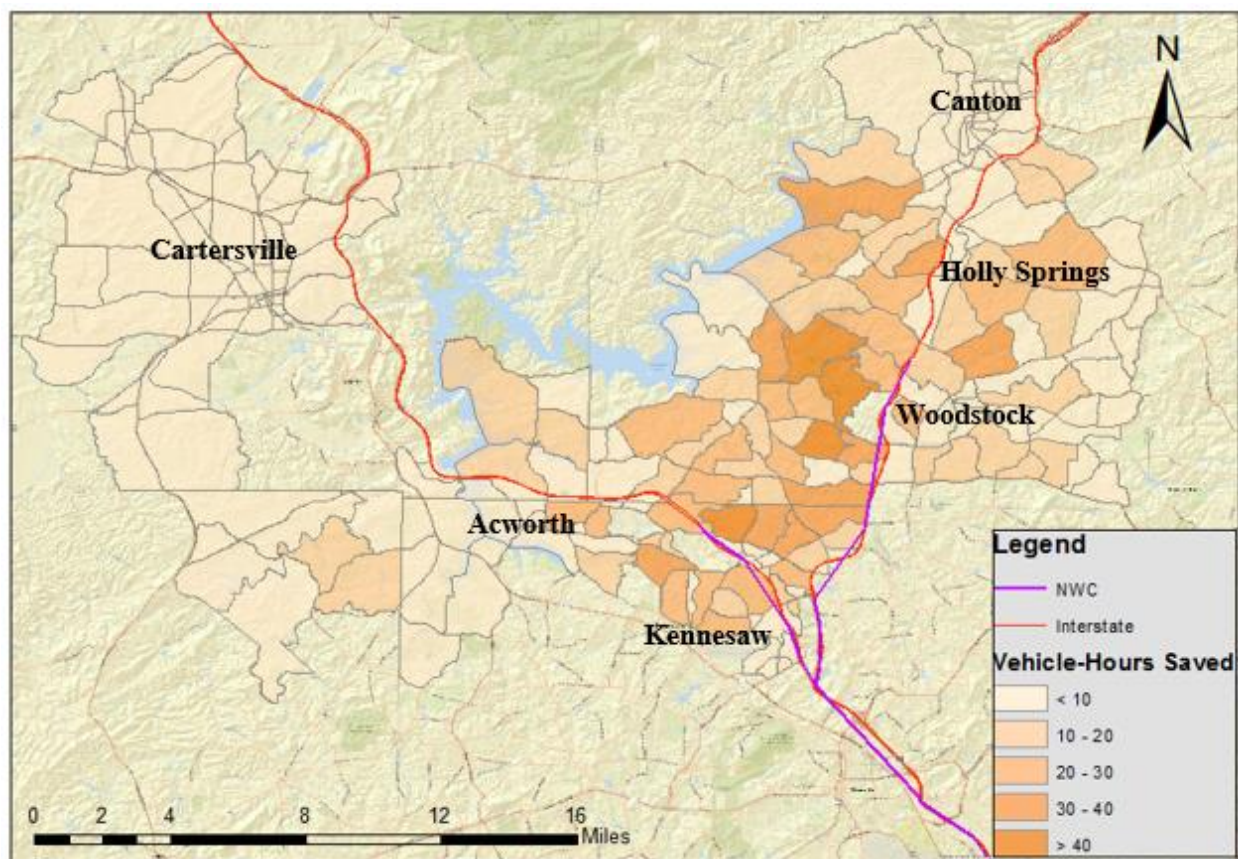


Figure 18. Spatial Distribution Vehicle-Hours Saved Grouped by Origin TAZ, from 6:30 - 8:30 A.M.

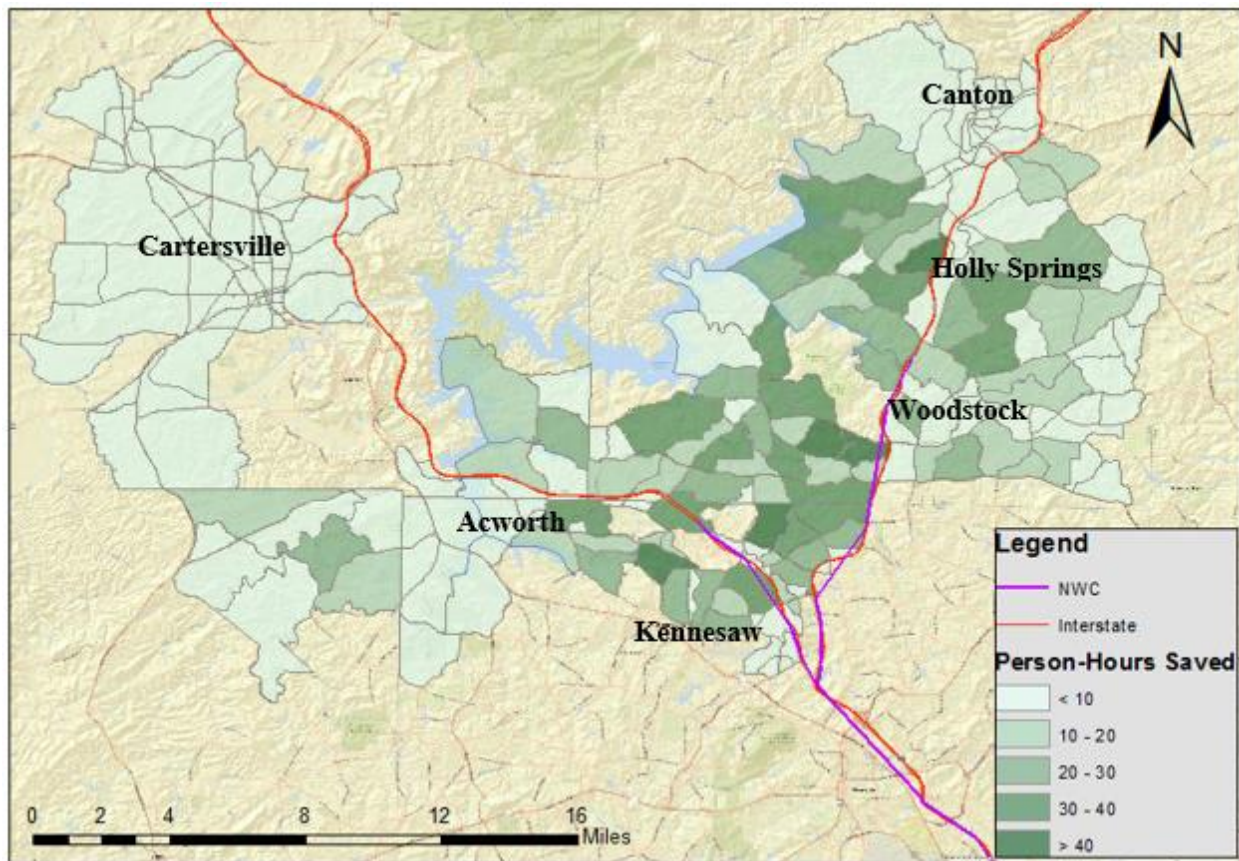


Figure 19. Spatial Distribution Person-Hours Saved Grouped by Origin TAZ, from 6:30 - 8:30 A.M.

Both maps show a very similar distribution pattern, with significantly more timesavings along the I-575 corridor in the East than along the I-75 in the West. This is expected because the NWC facilities extends longer on I-575 (10 miles) than on I-75 (5.8 miles) beyond the I-75 & I-575 split, thus is able to capture more trips generated within the commutershed. It is also worth noting that in this area, population is more concentrated along I-575 than along I-75, which also contributes to the more total hours saved along I-575.

CHAPTER 6. DIRECT ACCESS POINTS TIMESAVINGS

The NWC project is unique in that it's not only a managed lanes facility, but it also provides four additional direct access points that link the arterial roads directly to the NWC managed lanes. A photo of this kind of facility is shown in Figure 20. These four direct access points are all along I-75, at (from North to South) Hickory Grove Road, Big Shanty Road, Roswell Road and Terrell Mill Road, as shown in Figure 20. Unlike merge links that connect the managed lanes and the general purpose lanes, direct access points provide new access ramps to areas that were previously not served by the general purpose lane ramps before NWC managed lane construction. These access points are expected to create significant timesavings in the neighborhoods around the ramp area. This study further examines the timesavings of these four direct access points using the same methodology in Chapter 3, but inputs only the few TAZs around these direct access points as origins. The same parameters were used in section 4.3, except now the study areas are much smaller, defined as the TAZs that intersect the 0.5 radius from each access points. The sampled TAZs for each access point are shown below in Figure 21. The TAZs for Hickory Grove Road are shown in yellow, Big Shanty Road in blue, Roswell Road in green, and Terrell Mill Road in red.



Figure 20. Direct Access Point at Big Shanty Road @ I-75 (Google Map, 2019)

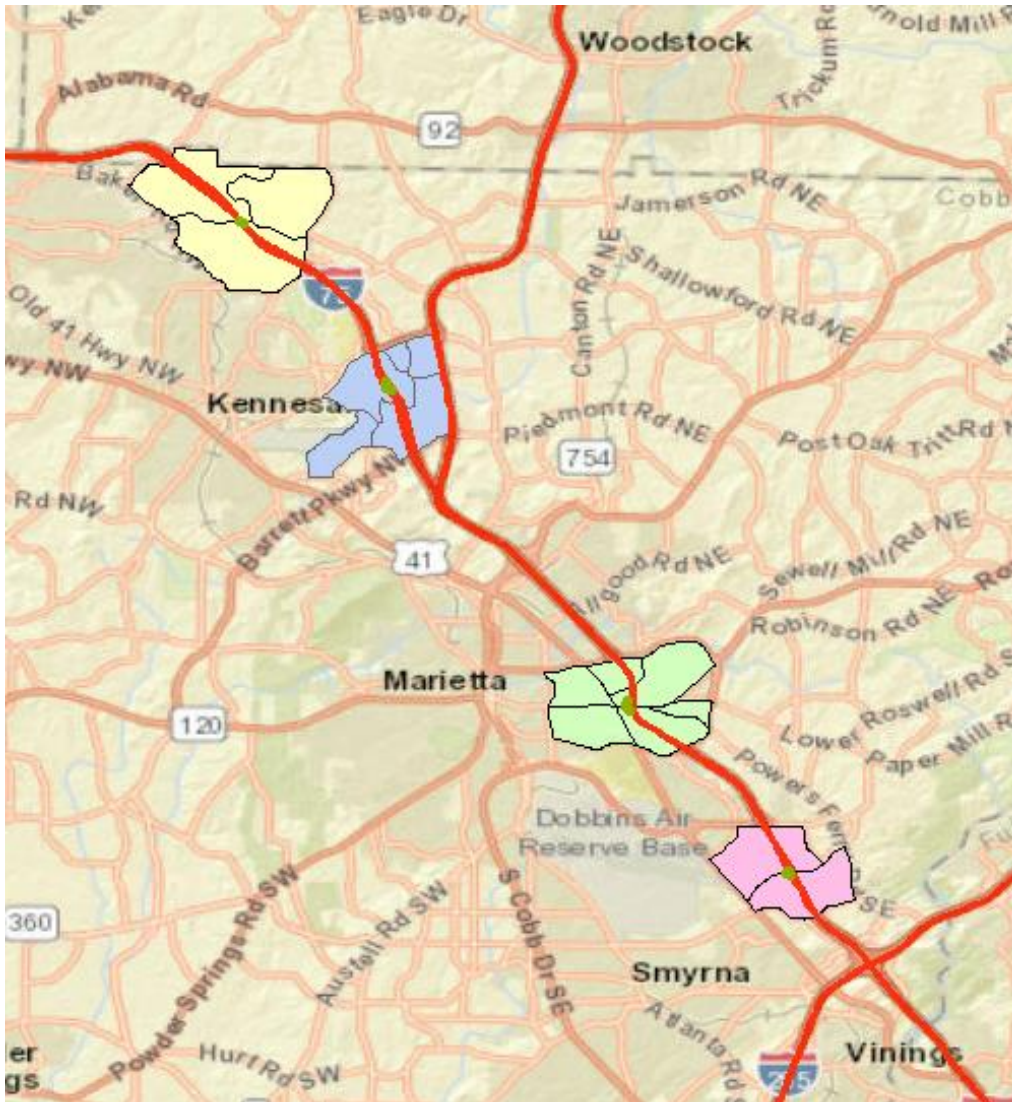


Figure 21. Location of the four Direct NWC Access Points and Their Sampled TAZs

The same trip O-D sampling methods are used in Section 4.2. The number of O-D pairs sampled for each site for entire two hour study period are shown below in Table 3. For this section, the study does not differentiate between the O-D pairs that do and do not use the NWC facility in the ABM, and assumes **all O-D pairs** generated in these TAZs are taking full advantage of the direct access ramps.

Table 3. Total O-D sampled from each Direct Access Points from 6:30 AM-8:30 AM

Site	Number of Origin TAZs	Number of Sampled O-D Pairs
Hickory Grove Road	5	1,039
Big Shanty Road	7	248
Roswell Road	9	568
Terrell Mill Road	4	704

Similar to Chapter 5, four 30-minute period scenario were run for each of the four access points (16 separate model runs), and the time difference for each individual O-D pairs were obtained and aggregated. This section presents the combined results for the four periods (6:30 – 8:30 A.M.) for each of the four access points.

6.1 Hickory Grove Road @ I-75

For all 1,039 O-D pairs that could access the Hickory Grove Road facility, the average travel time drops from 50.2 minutes to 37.1 minutes, resulting in a **26%** timesavings. The median travel time also drops from 51.0 minutes to 37.2 minutes. A frequency distribution map is shown below in Figure 22.

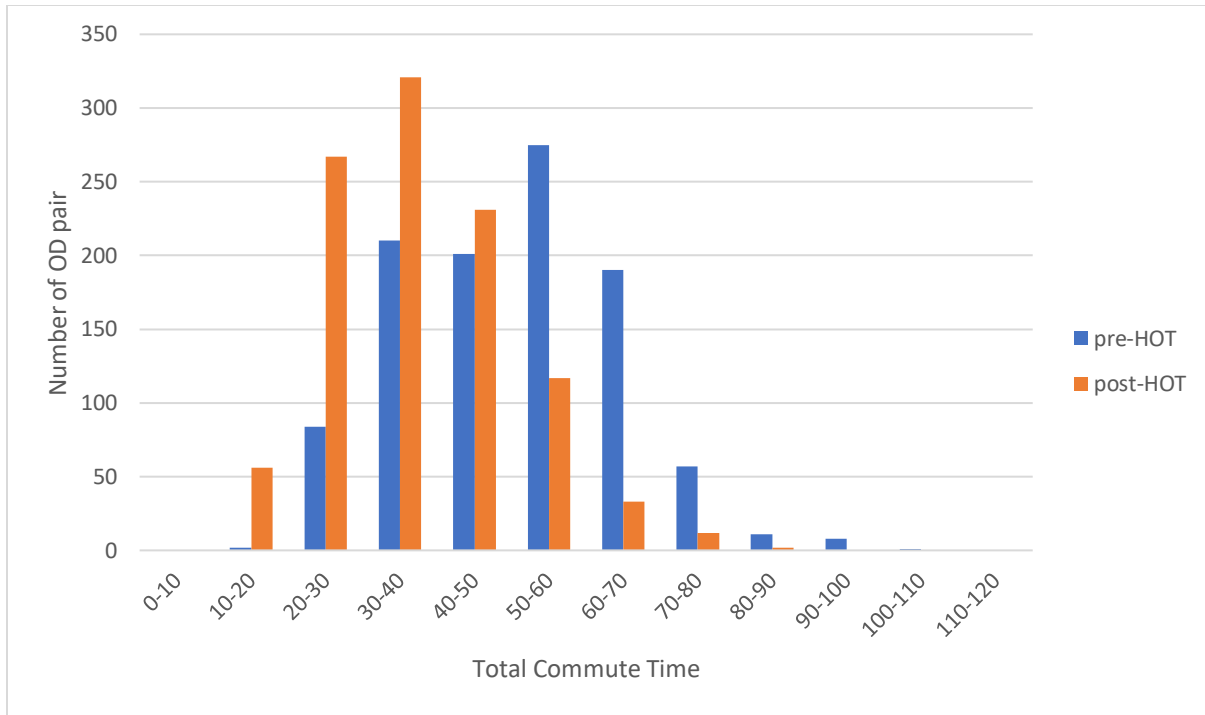


Figure 22. Timesavings at Hickory Grove Road Access Point from 6:30 - 8:30 A.M.

6.2 Big Shanty Road @ I-75

For all 248 O-D pairs that could access the Big Shanty Road facility, the average travel time drops from 49.2 minutes to 34.9 minutes, resulting in a **28.9%** timesavings. The median travel time also drops from 49.4 minutes to 34.6 minutes. A frequency distribution map is shown below in Figure 23.

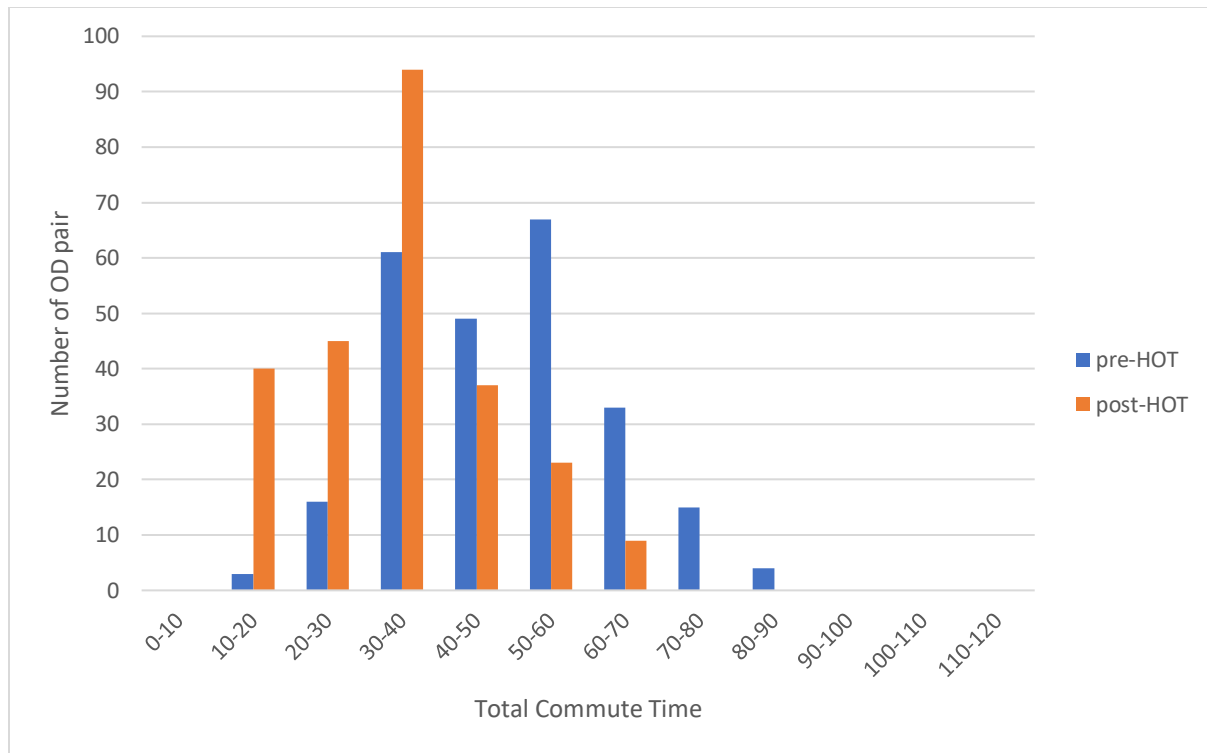


Figure 23. Timesavings at Big Shanty Road Access Point from 6:30 - 8:30 A.M.

6.3 Roswell Road @ I-75

For all 568 O-D pairs that could access the Roswell Road facility, the average travel time drops from 41.3 minutes to 36.1 minutes, resulting in a **12.5%** timesavings. The median travel time also drops from 39.4 minutes to 34.1 minutes. A frequency distribution map is shown below in Figure 24.

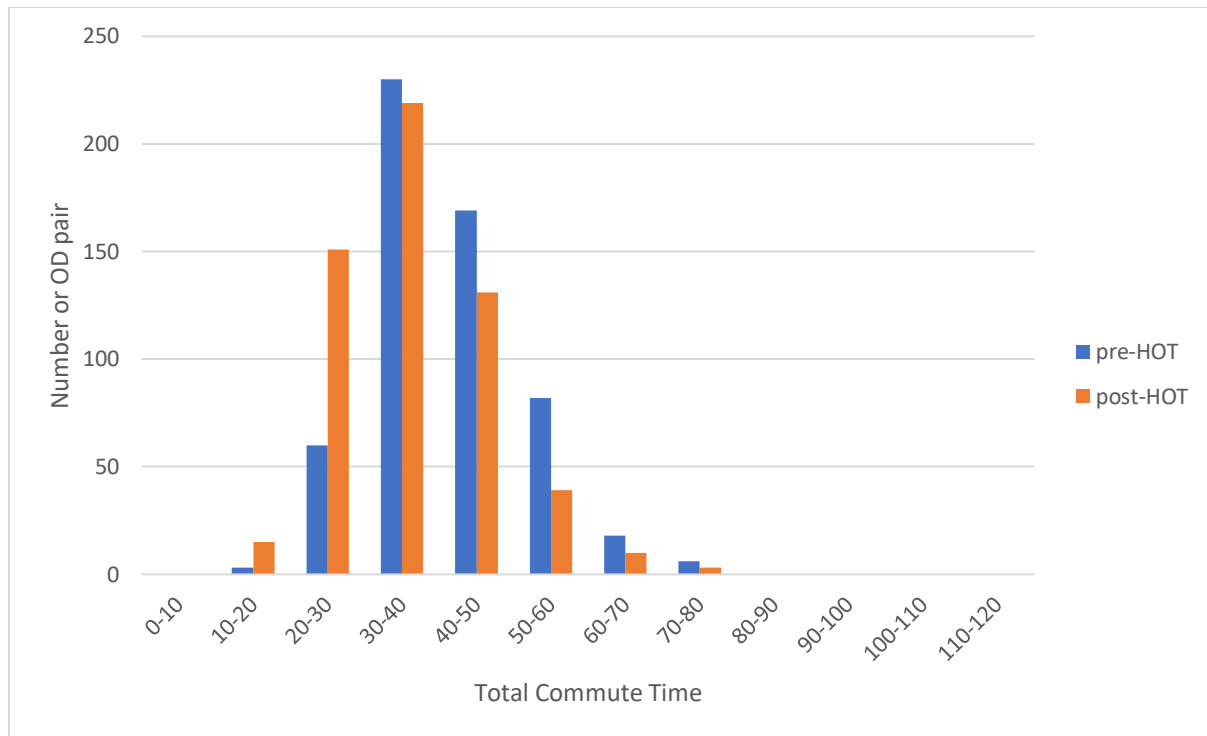


Figure 24. Timesavings at Roswell Road Access Point from 6:30 - 8:30 A.M.

6.4 Terrell Mill Road @ I-75

For all 704 O-D pairs that could access the Terrell Mill Road facility, the average travel time drops from 36.6 minutes to 33.0 minutes, resulting in a **10.0%** timesavings. The median travel time also drops from 35.1 minutes to 30.9 minutes. A frequency distribution map is shown below in Figure 25.

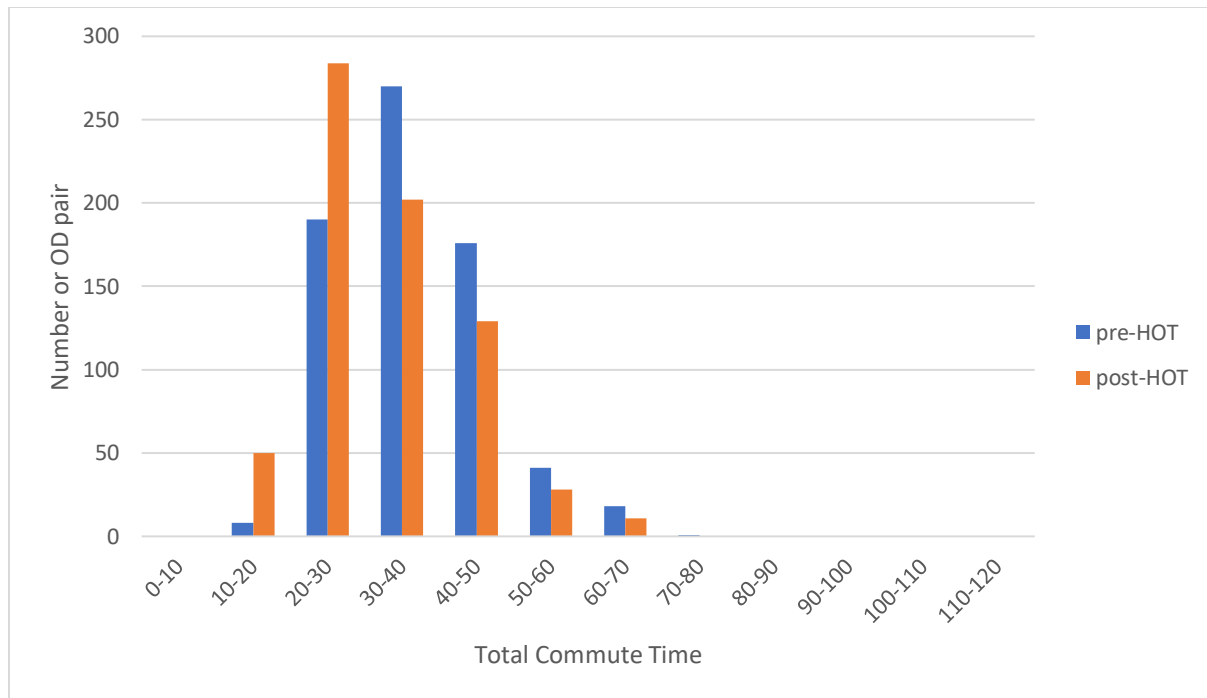


Figure 25. Timesavings at Terrell Mill Road Access Point from 6:30 - 8:30 A.M.

6.5 Summary

As expected, the timesavings becomes less significant towards the southern end of the NWC facility (i.e., Roswell Road and Terrell Mill Road). In the AM peak, the managed lanes are only open to southbound traffic, so for trips heading towards downtown, accessing the managed lanes in the southern access points would mean traveling fewer miles on the managed lanes, thus experiencing less timesavings. The minutes and percentage of timesavings between the four sites are shown below in Figure 26.

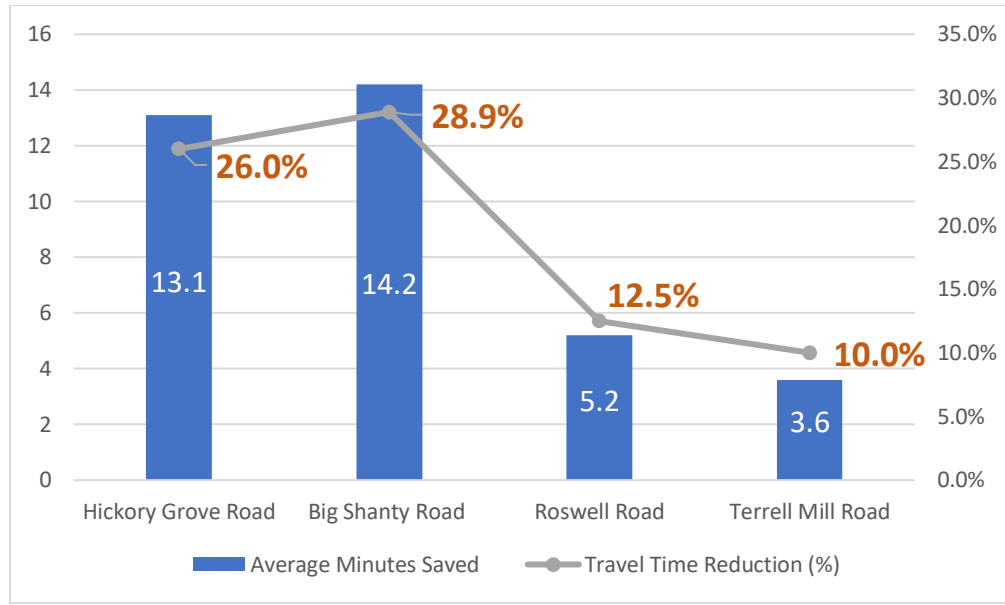


Figure 26. Travel Time Reduction (in percentage) and Average Timesavings (in minutes), for all four Access Points from 6:30 - 8:30 A.M.

It is also interesting to compare the timesavings in minutes with the distance from that access point to the southern end of the facility (at the I-75 & I-285 interchange). As shown in Figure 1, Hickory Grove Road is the northernmost entrance, and Terrell Mill Road is the closest. The distances and average minutes saved in each site are shown below in Table 4. Figure 27 shows this trend and correlation.

Table 4. Average Timesavings and Distance to NWC *Southern Managed Lane* End for all four Access Points

Access Point	Average Time Saved (Minutes)	Distance to the NWC Southern Managed Lane End (Miles)
Hickory Grove Road	13.1	15.4
Big Shanty Road	14.2	12.0
Roswell Road	5.2	5.6
Terrell Mill Road	3.6	2.1

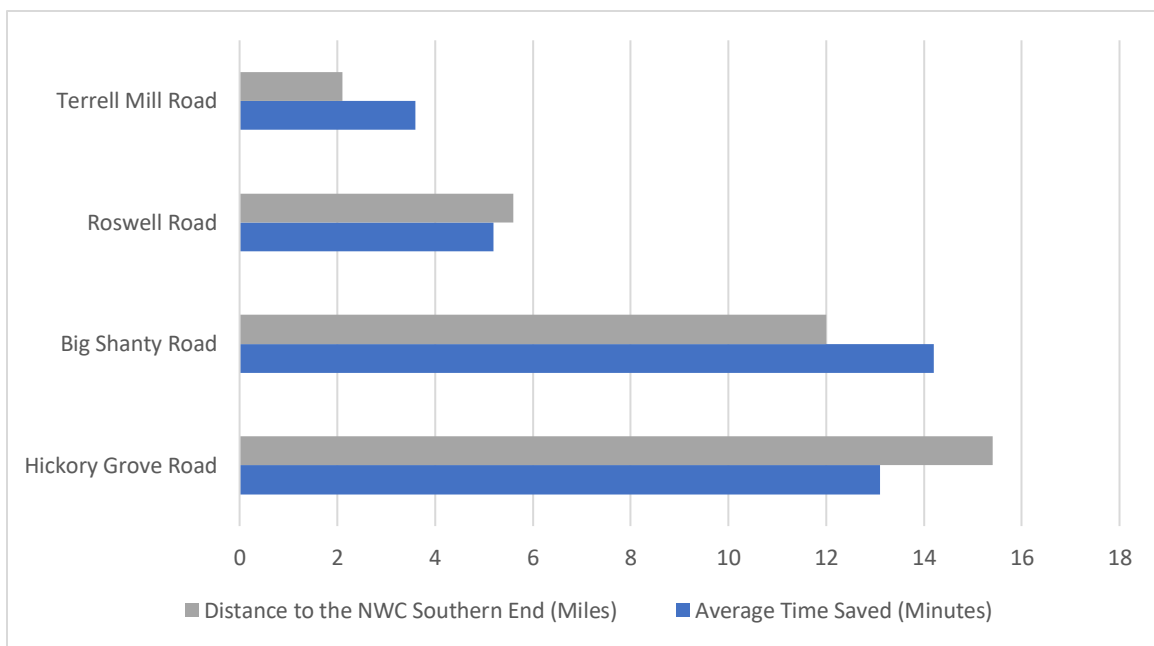


Figure 27. Graph of Average Timesavings and Distance to NWC Managed Lane End at all four Access Points

As show in Figure 26, the minutes saved at each access points are strongly related to their distance from the southern end of the managed lanes (and miles traversed on the managed lanes). Further analysis of the O-D route data for these trips will be needed assess how much of the time savings is associated with the more direct access to the managed lanes.

CHAPTER 7. CONCLUSIONS

This paper develops a framework that uses a regional transportation network graph with shortest path routing algorithms to estimate travel time through the network for any origin-destination pair. The team ran 32,174 trips predicted by the regional travel demand model to use the corridor through the shortest path routines to compare the difference in door-to-door travel route and travel time before and after the opening of Atlanta's NWC managed lane facility. The paper concludes that for trips that leave between the 6:30 -8:30 A.M., The NWC managed lanes users experience significant travel time reductions ranging from 21.0% to 27.1%. Minor speed improvements were also observed in the GP lanes post-construction expansion, so the GP lane users experience travel time reduction ranging from 5.8% to 12.0%. This result appears reasonable given previous experience in other cities with managed lane corridors that increase transportation network capacity. The subset of the 32,174 trips using the NWC managed lanes in the 6:30-8:30 A.M. time-period save 1138.8 vehicle-hours (1282.3 person-hours). The subset of NWC general purpose lane users in the 6:30-8:30 A.M. time period save a total of 1208.9 vehicle-hours (1482.2 person-hours). Although the total timesavings are comparable, the timesavings per GP lane user is much lower than the timesavings per managed lanes user (there are four times as many GP lane users as there are managed lanes users).

The paper also quantifies the timesavings specifically for the four dedicated access points by sampling trip that originate close from those points. A high correlation between the timesavings and its usable distance of NWC managed lane indicate that most users of the access points traverse the entire managed lane and takes full advantage of the facility.

Rather than using empirical data to estimate the timesavings of manage lanes, this study showcases the capability to obtain detailed route and travel time change information down to the link level through shortest path routing. This study is also unique in that the modeling results retain detailed trip attributes from the ABM model. Associated with the travel timesaving for each O-D pair is the trip taker's demographic information including household size, age, and work information. Further analysis can be performed to investigate the correlation of timesavings to different demographic groups. The ABM also contains the origin and destination zone of every trip, and can be easily traced back to observe if certain TAZs are benefiting more (accumulating more timesavings) than others.

The nature of this research framework means that it is suitable for travel time and routing impact study of any scale. Every new link speed and network data updated into the shortest path routing algorithm creates a new scenario. This means the method can not only be used for before and after travel time analysis, but also parallel comparison of travel time impact of different projects, or a combination of both. The input origin and destination pair can also be assigned anywhere in the given network, giving users a wide choice of geographical locations to observe the impact of any transportation project.

CHAPTER 8. LIMITATIONS AND FUTURE WORK

The scope of this paper limits the analysis to four 30-minute timeframe in the A.M. peak, from 6:30 to 8:30 A.M., but the same analysis for other times of the day can be easily obtained, as long as speed data for the selected timeframe is available. For this paper, the team focused on long distance vehicular commute trips, and assessed 29,793 unique O-D pairs that account for 32,174 trips. These represent 66.4% of all unique O-D pairs and 46.9% of all such trips that leave from the 255-TAZ study area defined in section 4.1.2. For future work, the team will conduct the same analysis for the entire day to assess the changes in timesavings as the day progresses. The result will yield travel time savings per day and per year for use in cost-benefit analysis. It is also worth noting that the same research framework is also applicable to other metro areas, by simply updating the roadway network and link speeds. The RoadwaySim module was designed to be a powerful tool to evaluate travel time, energy use, and monetary cost of different commute modes. The next stage of the research will assess the energy savings and emissions reductions from the NWC.

In addition, this paper neglects the NWC managed lanes impact on transit services in the area. According to the ABM, only 1.6% of trips in the Commutershed area between the selected timeframe use transit service. However, CobbLinc, the main local transit provider in the area, operates eight bus routes that take the I-75, and SRTA also operates four Xpress bus lines to and from Downtown Atlanta on I-75. Transit vehicle automatically have access to the NWC managed lanes, so the travel time on these routes should be very different. It is suggested for future research to conduct the same analysis with the complete Commute Alternatives platform

(RoadwaySim and TransitSim) and input the latest GTFS data from CobbLinc and SRTA to obtain travel time change for all users including transit users.

Lastly, this paper acknowledges potential data inaccuracy, specifically the input speed data. As the nature of this research is preliminary, the speed data has not gone through a thorough QA/QC process. The SRTA and NaviGator speed data locations were manually geocoded to match the 203k link network for this research. For the next step of the research, not only should input speed data been completely QA/QC'ed, but a more streamlined, automated process that geo-links the speed data and the network shapefile should be established.

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